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A BIOMECHANICAL ANALYSIS OF THE HANDSTAND TO HANDSTAND STALDER CIRCLE ON THE UNEVEN PARALLEL BARS

by

© DAYNA BETH DANIELS

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDY AND RESEARCH
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FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled ..A Biomechanical Analysis of the Handstand to Handstand Stalder Circle on the Uneven Parallel Bars........

submitted by ..Dayna Beth Daniels..............

in partial fulfillment of the requirements for the degree of Doctor of Philosophy

DEDICATION

This dissertation is dedicated to
Harriett M. Carnes

ABSTRACT

The purpose of the study was to carry out a biomechanical analysis of the handstand to handstand Stalder circle on the uneven parallel bars using cinematography. Statistical analysis of the data was then undertaken to determine if any significant differences in performance existed between successful Stalders.

Fourteen Class I and Elite level female gymnasts from Canada and the United States were the subjects in the study. Subjects were filmed, with one camera in the mid-sagittal plane, performing two Stalders. Following collection of the data, a panel of nine gymnasts judges ranked the Stalders from best to poorest as the trials compared to one another. An overall ranking was determined and four groups of seven trials each were formed by equally dividing the ranking. Group I trials were considered to be excellent Stalder performances. Group IV trials were considered to be poor performances as compared to the Group I trials. The following are the major findings of the study: (1) beginning the Stalder in a handstand position puts the gymnast in a position to potentially produce maximum amounts of angular momentum and kinetic energy in the down swing to aid in performance of the up swing, (2) delaying the straddle-in and performing the action slowly contributes to

the maximization of the moment of inertia which effects the values of angular momentum and kinetic energy, (3) minimum shoulder extension throughout the Stalder was the single most important performance factor to success in the skill (4) indirect force measurements calculated from cinematographic data revealed that gymnasts had to withstand forces of 1.99 to 3.30 times their body weight at the bottom of the swing in good Stalder performances, (5) timing the straddle-out action with the recoil of the rail in the up swing aids in performance of the Stalder.

A variety of performance styles can be utilized to execute successful Stalders. The study showed that an initial handstand position, minimal shoulder flexion to produce a body position in which the hips are always farther from the rail than the shoulders, and a straddle-out action of gradual hip extension, completed following full shoulder flexion contribute to production of large amounts of angular momentum and kinetic energy necessary for good amplitude and swing in the performance of the Stalder. This performance style may also be the most effective technique to use for minimizing deductions in a competitive situation.

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CHAPTER I

THE PROBLEM

Introduction

> "Then seemingly for those two elements of the soul, the spiritual and the philosophic, God I should say, has given men the two arts, music and gymnastics. Only incidently do they serve soul and body. The purpose is to tune these two elements into harmony with one another by slackening or tightening, till the proper pitch be reached... Then we shall rightly name as the perfect master of music and understander of harmony not him who can attune the strings, but him who can most fairly mix music and gymnastics and apply them in the most perfect measure to the soul (Plato, The Republic Book III)."

> "The renaissance of gymnastics will soon disappear if doctors and gymnasts do not seek to come nearer to it scientifically (P.H. Ling 1774-1839)."

Biomechanics, the study of forces and their effects on the human body, is one of the oldest sciences known to man. Since the time of Aristotle, men have observed and hypothesized about man's movements. Archimedes, daVinci, Borelli, and Newton formulated ideas about man and his relationship to the physical sciences. The ideas they set forth have withstood the test of time and set a strong foundation for today's studies in biomechanics (Cooper and Glassow, 1976).

The application of biomechanical techniques to the study of sport has had tremendous effect on both the sport world and the rapid growth and exposure of the science. The

growth of all sport sciences has given the coach and athlete a deeper understanding of the scientific basis of their sport. Consequently, the coach's demand for more accurate information has prompted a surge of sport research. Biomechanics has come of age and matured into a highly sophisticated and widely accepted applied science with a recognizable body of knowledge and research tools.

The application of biomechanical techniques to the analysis of sport skills can aid the coach and athlete by reducing the time it takes to thoroughly understand all the kinematic and kinetic factors associated with a particular skill or determine the feasibility of a new performance technique. This knowledge can aid the coach in the development of training regimens and progressions for skill development for athletes of all levels.

Many elements in the sport of gymnastics are planar and lend themselves easily to biomechanical analysis. Due to the nature of the sport and its apparatus demands, failure to utilize sound mechanics in the performance of skills usually results in incompleted movements or unaesthetic execution. Much of the gymnastics literature published in the decade of the 1970's includes explanations of the mechanical principles involved in the movements. Although qualitative studies comprised the majority of gymnastics literature, a number of quantitative analyses were also found. Unfortunately, the biomechanical analyses of these

gymnastics elements came after their execution in competitive situations; usually at the world level and, therefore, after at least a basic understanding of the forces and principles involved had been figured out by the coaches.

One shortcoming in the biomechanics research conducted in the gymnastics area is that while good descriptive, kinematic studies have been conducted, little or no statistical investigation of the data has been undertaken. While it is necessary for coaches to have a thorough knowledge of the skill pattern, without the knowledge of the factors that significantly contribute to successful execution, the coach is still faced with having to use intuition and trial/error methods to develop progressions of skill learning and training procedures through which the athletes can benefit.

The Stalder family of movements on the uneven parallel bars is becoming a very important element in the composition of routines at the international level. The 1976-80 World Compulsory uneven parallel bars routine contained a Stalder element. "The purpose of a compulsory routine in artistic gymnastics, as with school figures in competitive ice skating, is to set a standard by which all gymnasts can be judged equally. The required elements in a compulsory routine reflect the ideas of the F.I.G. [International Federation of Gymnastics] as to which elements represent

basic skills which are to be mastered by all competitive gymnasts at the world level (Prendergast, 1980)." Inclusion of a Stalder element in the World Class compulsory makes a strong statement that the Stalder is basic to high level competition. Most often skills included in compulsory routines become popular elements in optional routines. "It is almost expected that these elements or variations of them be included in the optional routines until the level of difficulty in general surpasses those movements (Prendergast, 1980)."

Inclusion of a Stalder element in an optional routine accounts for superior ("C") level difficulty, fulfills compositional requirements for circles about the bar, can add originality and rare value bonus marks depending on the connections, fulfills above and below bar action as required, and may add to the overall virtuosity of the routine (F.I.G., 1979). The possible points accumulated just from including a Stalder element in a routine can be considerable, particularly if the movement is performed such that it adds execution and amplitude marks to the gymnast's score. In international competition where compositional requirements will be complete and execution/amplitude is generally high among all competitors, the higher scores will be awarded to those gymnasts whose routines swing, are original in connections, and show risk. In the 1978 World Championships in Strassborg, France, Marcia Frederick of the United States won the gold medal on the uneven parallel

bars. This unprecedented victory was attributed to her daring risk, swing, and personal technique (Criley, 1978). Her routine contained many Stalder elements. The inclusion of Stalders in a routine may or may not be the deciding factor in a gymnast's score. To Marcia Frederick they represented an important part of her victory. She even named her Great Dane puppy Stalder (Tanner, 1980)!

Many elements of difficulty performed in women's gymnastics are moves adapted from men's apparatus. Coaches, for the most part, must rely on trial and error methods to develop progressions and performance styles suitable to the female gymnast. It is therefore imperative that sound research be conducted on women performing new elements to ascertain the critical variables which directly affect their performance. The Stalder has primarily been performed on the men's horizontal bar. However, this element is becoming basic to the composition of uneven parallel bars routines at the elite and international levels of competition. A thorough analysis of the Stalder will not only aid coaches in training female gymnasts for the specific performance of the Stalder, but it will also identify the critical variables of execution so that gymnasts may begin to master the components of performance of this basic skill earlier in their competitive careers.

STATEMENT OF THE PROBLEM

The underlying responsibility of the sports biomechanist is to provide the teacher/coach with useful information on the description and performance of sports skills and limiting factors to successful performance. The purpose of the study was to investigate the handstand to handstand Stalder circle [Stalder] on the uneven parallel bars and to isolate variables which directly influence the performance of the skill. Investigation of the problem invoked examination of the following subproblems:

1. Identification of the temporal, kinematic, and kinetic factors involved in the performance of the Stalder.

2. Identification of the anthropometric, strength, and flexibility measures which contribute to the successful execution of the Stalder.

3. Identification of kinematic and kinetic variables which contribute to a good Stalder performance according to evaluation by trained gymnastics judges.

4. Investigation of the statistical relationships between and among all the variables to isolate the factors most critical to successful Stalder performance.

DELIMITATIONS

The study was delimited:

1. To ten Class I and three Elite gymnasts from the United States and one Elite Level III Canadian gymnast. All Elite level gymnasts were World Class caliber.

2. To performance of handstand to handstand Stalder circles on the uneven parallel bars.

3. To a 2-dimensional cinematographic and segmental analysis of the movement as seen in the sagittal plane.

4. To analysis of selected temporal, kinematic, and kinetic measures of the Stalder and the statistical relationships among them.

DEFINITION OF TERMS

Definition of the following terms is presented to add clarity to the study.

Amplitude. The degree to which an element is taken to its fullest in extension, utilization of space, and swing. This term can refer to internal amplitude, the amount of stretch or the actual measure of articular displacement, or external amplitude, the space between the gymnast and the rail.

Bottom Swing. That portion of the Stalder in which the gymnast is passing below the rail.

Code of Points. The rule book outlining all requirements, deductions, and instructions on routine construction, judging, and meet conduct. It is published by the Women's Technical Committee of the F.I.G.

Compulsory. An exercise of fixed format and composition which must be performed exactly, by all gymnasts, in specified competitions.

Difficulty. a) An element executed and awarded points based on the level of performance with respect to all other elements.

b) A category in the point breakdown which specifies maximum points for the performance of skills from different categories and for specific competitions.

Down Swing. The initial 180 degrees of rotation (or any part thereof) of the Stalder circle beginning with the gymnast directly above the bar (or at her initial highest position) until the gymnast is directly below the rail.

Execution. The mechanical correctness of the performance of an element.

F.I.G.. International Gymnastics Federation. The governing body of international gymnastics.

Handstand. An inverted, balanced position in which the gymnast assumes a posture of full shoulder flexion, straight torso and legs, with the head in a neutral position. Deviations from a straight position constitute a poorly executed handstand.

Handstand to Handstand Stalder Circle. A 360 degree rotation about a bar in which the gymnast's only support is an overgrip by the hands. The movement begins in a handstand with the body position changing to an inverted straddle dorsal hang by the end of the down swing and returning to a handstand position by the completion of the up swing.

Inverted Dorsal Hang. A position in which the gymnast is fully flexed at the hip joint and is suspended by the hands from a rail. The abdomen faces the rail.

Judge. An impartial referee, trained to evaluate gymnastics performance according to the Code of Points.

Muscling. A slang expression used to describe an execution technique of forceably attaining a position through noticeable muscular effort as opposed to swinging to completion.

Optional. An exercise created entirely by the gymnast/ coach. The composition of this exercise is decided freely within the guidelines of the Code of Points.

Overgrip. A grasp of a rail with both hands and with the arms in pronation.

Point Breakdown. A specific listing in the Code of Points of categories and deductions by which optional exercises are evaluated.

Rock Back. Following the straddle-in, that portion of the Stalder in which the gymnast rotates downward to an inverted dorsal hang prior to the bottom swing.

Straddle-in. The first part of the Stalder during which the gymnast goes from the initial handstand to a position of flexion at the hips prior to the rock back.

Straddle-out. That portion of the Stalder during which the gymnast returns from an inverted dorsal hang to a handstand position.

Up Swing. The final 180 degrees of rotation (or any part thereof) of a Stalder circle beginning with the gymnast directly below the bar and ending when the gymnast reaches her highest point.

CHAPTER II

REVIEW OF RELATED LITERATURE

This chapter is organized into two major divisions of literature review: (1) Stalder Action and (2) Strength Measures.

STALDER ACTION

One of the greatest honors bestowed upon a gymnast is that of having a new movement named after the gymnast who created it or first performed it in competition. Often these gymnasts are Olympic gold medalists in the event in which a move carries their name. One such gymnast was Josef Stalder from Switzerland. Stalder won the gold medal in the combined horizontal bar exercises at the XIII Olympic Games in London, England in 1948 (McWhirter, 1976). The Stalder element was named after him (Kaneko, 1976).

The Stalder action involves a 360 degree rotation about a bar beginning and ending with the body in a handstand position. Within the course of the circle the gymnast attains an inverted dorsal hang position. Because of the changes in body position this movement combines the mechanics from both long and short circling actions (Kunzle, 1957). Movements of this type are becoming more popular in uneven parallel bars exercises. "They are often used in exercises as a means of contrast, and all have, with their element of surprise, a dramatic effect. Although none of

them is easy, some should be within the compass of average performers. Others, such as the straddle-in and out [Stalder], are in the very highest class, suitable only for the very advanced gymnasts (Kunzle, 1957)."

Gravity acting on the gymnast provides the force which causes sufficient angular momentum to allow the gymnast to circle the bar (Osborne, 1978). The circling forces acting on the gymnast throughout the swing can be resolved into two components - one normal to the action and acting toward the center of curvature of the swing and one component tangential to the swing (Plagenhoef, 1971). The tangential component serves to accelerate the gymnast in the direction in which it acts (Hay, 1978). Thus, the longer gravity can act during the down swing, the greater the angular acceleration to be realized. A gymnast must attempt to cast to a full handstand position prior to beginning the down swing of the Stalder to achieve a position for the potentially greatest downward acceleration (Kunzle, 1957; George, 1980). The tangential component of force is computed from: $mr\alpha$, where m is the mass of the subject, r is the radius of rotation and α (alpha) is the angular acceleration of the body (Meriam, 1978). The length of the radius of rotation adds to the value of the tangential component. The longer the radius of rotation, the greater the moment of inertia of the system. Angular momentum (H), being a product of the moment of inertia (I) and the angular velocity ω, can be maximized with a long radius of rotation

(Hopper, 1978). The gymnast must also attempt to swing downward with as great a radius of rotation as possible to maximize descent phase amplitude. This will aid in establishing the greatest potential for swing amplitude in the ascent phase (George, 1980).

The normal component of angular momentum always acts toward the center of curvature (Meriam, 1978). Thus, the gymnasts' center of mass is constantly changing position being compelled to move in a curved path (Barham, 1978). The normal component is obtained from the equation:

$$a_n = V^2/r + G \cos \theta$$

(Hay, 1979) where V2/r is the squared velocity divided by the radius of rotation and G cos θ is the mass of the object at any position. This component is also of great importance to the gymnast in the execution of circling movements. Kunzle (1957) stated that the gymnast must withstand normal forces of up to four times the body weight of the gymnast at the bottom of a giant swing. Cureton (1939) measured forces of up to five times the body weight for the same skill element. Sale and Judd (1974), measuring forces for the giant swing on the still rings, obtained values of 4.8 to 5.4 times the body weight. Hay, Putnam, and Wilson (1979), studying the forces against the uneven parallel bars, used female subjects performing a cast from the high bar to a back hip circle on the low bar. They reported forces of 3.38 to 3.60 times the body weight of their subjects. The

combined effects of the normal and tangential components of the acting forces is to be one of maximized velocity and acceleration at the bottom of the down swing to maximize potential for the technical execution and amplitude on the up swing (George, 1980).

It is the aim of the gymnast to gain more momentum on the descent phase than is lost in the ascent phase (Osborne, 1978). Forces act in opposition to the positive effects of gravity during the down swing. George (1980) attributed some loss of energy to grip friction and air resistance which would not effect the swing in a frictionless state. Hay (1978) stated that air resistance is a negligible factor and can be considered insignificant in hindering the swing. Dainis (1975) stated that "the forces caused by grip friction are quite small compared to the forces acting to swing the body about the bar." None of these sources supported their statements with quantitative data. To offset this energy loss the gymnast must perform some muscular work in order to complete the circling action. The gymnast must adjust the body position to reduce the moment of inertia in order to ease the ascent phase of the swing (Osborne, 1978). A gymnast has two basic ways in which to change the moment of inertia of the body (Kunzle, 1957). One method is to bend the elbows to bring the center of mass closer to the rail. The other technique used by gymnasts is to use subtle actions of the trunk and hips to achieve the same ends.

The literature available on Stalder circles has been limited exclusively to performance of the move by men on the horizontal bar (George, 1969; Osborne, 1978; Kunzle, 1957; Shurlock, 1964; Kaneko, 1976). The research has been solely qualitative description of the general Stalder action. There is much agreement in the literature on the gross patterns of the Stalder, however, no kinetic or even kinematic data has been presented thus far to support any of these analyses.

Osborne (1978) identified two styles of Stalder execution which he terms early- and late straddle-in techniques. George (1969) stated that the "straddle-in action is the single most important variable in executing a proper Stalder." Shurlock (1964) suggested that the straddle should be as wide as possible as the feet pass over the bar and are brought in closer to the armpits. It was stressed by Osborne (1978), Kunzle (1957), Dainis (1975), and George (1969) that maximizing the moment of inertia on the down swing is critical to attaining the greatest possible angular momentum. The wide straddle necessitates the hips being brought closer to the bar thus shortening the radius of rotation and reducing the moment of inertia. George's (1969) statement that the straddle of the legs be kept as narrow as possible is more conducive to the effort of maximizing the moment of inertia. Passing the feet close to the bar on the straddle-in phase will help to reduce the torque about the hips and will aid in the execution of that

phase (Osborne, 1978).

The straddle-in action is to be instantaneous, vigorous, and complete to reduce the torques about the hip and shoulder articulations (George, 1969). The hip pike must be timed so that the gymnast has the maximum momentum and yet can still succeed in executing the straddle-in (Kunzle, 1957). Extension of the arms at the shoulders should be delayed until the flexion of the legs to the trunk at the hips is initiated. The back is kept as flat as possible throughout this action to maximize the distance between the center of mass and the rail (George, 1969). This action occurs near the top most portion of the down swing. The late straddle-in action identified by Osborne (1978) necessitates maintaining the extended (handstand) position longer into the down swing. Extension of the arms at the shoulder joint occurs first followed by flexion at the hip joint. Delaying the final extension of the arms at the shoulder until well into the down swing can increase the angular momentum in the down swing by increasing the moment of inertia (Osborne, 1978). Once the straddle-in action has occurred, the gymnast must still attempt to keep the moment of inertia as great as possible. Shurlock (1964) suggested keeping the legs near the armpits. George (1969) best described the action as one which requires "one's full anatomical range of motion with reference to the hip region."

"The result of your considerable momentum in the straddle circle and the leg beat downwards as you swing back is the tremendous pull on the bar. Here lies the crux of the movement. If you can withstand the jerk on the hands, the bar whips down as it gathers the energy from the body, then reacts sharply, throwing the shoulders and hips sharply upwards (Kunzle, 1957)." "Obviously you keep the arms quite straight until the moment that they go slack after the reaction from the bar. If you do not, the pull at the bottom will jerk you off (Kunzle, 1957)." This description, though not scientifically enlightening, is a common belief expressed in the literature. This is often referred to as the bottoming effect (George, 1980). The forces acting at the bottom of the swing can be more than four times the weight of the gymnast (Kunzle, 1957). Unfolding from the pike position is a common occurrence (George, 1969). The ability to maintain an adequately decreased shoulder angle through the bottom of the swing is critical to the successful completion of the skill. The downward forces will tend to enhance the position of the legs relative to the trunk, therefore, this is not often a factor in a gymnast's inability to control the bottoming effect (George, 1969).

The straddle-out action must be carefully timed. George (1969) suggested that the downward bowing of the rail in the bottoming effect should be the "tactical cue" for the initiation of the straddle-out. Shurlock reported that a

feeling of 'weightlessness' occurs at approximately a horizontal position on the up swing. It is at this point that the straddle-out should begin. George (1969) suggested that shoulder flexion and hip extension occur simultaneously. If timed properly, the gymnast can achieve a handstand position with relative ease. The straddle-out of the legs should be as wide as possible attempting to keep the motion in the frontal plane. This helps to reduce the moment of inertia, and thus, torque about the hip joint (Osborne, 1978). Also, at this point of 'weightlessness', a 'slip grip' action of the hands at the wrist occurs. The "wrists are arched onto the top of the bar to provide support for the oncoming body weight (George, 1969)."

In one point of disagreement, Osborne (1978) suggested that hip extension can hinder shoulder flexion if these actions occur simultaneously. Hip extension can be delayed until shoulder flexion is almost complete. This action can be supported by Plagenhoef (1971). He described the relative motion of the segments in a three link system in which the motion of one segment directly effects the motion of the other segments. Action of one segment at a time enhances the execution of the total skill.

STRENGTH MEASURES

The strength requirements of the gymnast to successfully perform a Stalder are primarily from isometric contractions to maintain the straddle-in position at the

bottom of the down swing. The forces that must be controlled at the hip and shoulder joints are greatest in this position (George, 1969). Grip strength tests have been an integral part of strength test batteries since the 1880's. Total body strength can be represented quite adequately through grip strength measures (Bowers, 1961; Everett and Sills, 1952). This test has been shown to be a reliable measure of overall body strength and an excellent measure for activities involving isometric contractions of forearm stabilizers (deVries, 1974). Static strength or a single maximum effort by a subject in a fixed position can be easily measured using dynamometers and the results are quite reliable (deVries, 1976; Hunsicker and Greey, 1957). This type of measure is appropriate to determine the strength of a gymnast performing a Stalder as the position of the body is relatively fixed throughout the part of the skill where strength is critical; the bottom of the down swing. Hunsicker and Greey (1957) reported that relatively little difference in strength is found between the two sides of the body.

Grip strength is highly correlated to weight (Pierson and O'Connell, 1962; Everett and Sills, 1952; Bowers, 1961) and has also been highly related to a mesomorphic somatotype (Pierson and O'Connell, 1962). Female gymnasts are often somatotyped around a 3 - 5 - 3 rating. This indicates a high mesomorphic or muscular component to their physique (Matthews and Fox, 1976).

CHAPTER III

METHODS AND PROCEDURES

The experimental methods for data collection and analysis used in the study are presented under the following headings: (1) General Procedures; (2) Cinematographic Procedures; (3) Data Analysis Procedures; (4) Judging Panel and Trial Ranking and (5) Statistical Procedures.

GENERAL PROCEDURES

Subject Selection

The study was carried out utilizing 14 gymnasts. The subjects selected for the study were one Elite Level III Canadian gymnast, three Elite and ten Class I gymnasts from the United States. Criterion for selection was the gymnasts' ability to perform a Stalder without the aid of spotting assistance. Data was collected in the latter portion of the competitive season.

Anthropometric Measures

For the purpose of investigating differences among subjects the following measures were taken:

(1) Mass. Standard balance scales were used to obtain the weight of the subjects. Mass was calculated from this measure. This procedure was performed directly prior to the data collection sessions.

(2) Height. The height of each subject was measured using a metric tape.

(3) Upper extremity length was measured from the centroid of the glenohumeral joint to the distal head of the fifth metacarpal of the hand with the elbow joint in full extension. The distal head of the fifth metacarpal was chosen to represent the endpoint of the upper extremity because the fingers were wrapped around the bar during the skill and, therefore, did not contribute length to the body segment or to the total radius of the body in rotation about the bar.

(4) Lower extremity length was measured from the centroid of the hip joint to the distal head of the fifth metatarsal of the foot.

(5) Trunk length was measured from the centroid of the glenohumeral joint (proximal endpoint of the upper extremity) to the centroid of the hip joint (proximal endpoint of the lower extremity).

These endpoints corresponded to the segmental endpoints used in digitizing procedures. Upper extremity, lower extremity and trunk lengths were obtained from the digitized data for all subjects.

Flexibility Measures

Full range of motion in shoulder and hip articulations is recognized as an important factor in gymnastics performance. The flexibility in these joints was measured. For permanent records of active flexibility measures at the time of data collection 35mm still photographs were taken of each subject. For measures of shoulder flexibility, gymnasts were seated on a mat with the legs and back straight. The arms were flexed at the shoulder joint to the maximum range of motion the gymnast could attain without elbow flexion or forward pelvic rotation. The measure taken was the angle formed between the longitudinal axis of the upper extremity and the frontal plane above the shoulder. For measures of hip flexibility, the gymnasts attained an inverted dorsal hang position (legs straddled) on the low rail of a set of uneven parallel bars. The measure taken was the angle representing the flexion of the thighs to the trunk. Photographs were taken with an Olympus OM-1 SLR camera outfitted with a 50mm Zuiko lens f16 to f1.8, and loaded with Kodak Tri-X film, ASA 400. Camera placement was 90 degrees to the sagittal plane of the action. A computer program to calculate angles from the line slopes of connected body segments was utilized. Segmental endpoints of the arm, thigh, and trunk were digitized to determine lines of body segments for which slopes were then calculated. The angle formed by the intersection of the two slopes was found

by using the formula:

$$\tan \theta^{-1,2} = (M2-M1)/(1+M1M2)$$

where tan θ designates the angle from line 1 to line 2 and M is the slope of each line.

Strength Measures

Grip strength of both hands of all subjects was measured using a Stoelting Hand Dynamometer (C.H. Stoelting Co., Chicago, Illinois, U.S.A.) with a full scale measure of 100kg. in one kilogram increments. The mean grip strength for each subject was calculated and used as the independent variable measure for overall muscular strength.

CINEMATOGRAPHIC PROCEDURES

The filming was conducted in the training facilities of the Oregon Academy of Artistic Gymnastics (National Division), Eugene, Oregon, U.S.A. Two filming sessions were required to film all fourteen gymnasts. Subjects performed two Stalders each on the high bar facing away from the low bar. The gymnasts executed both trials consecutively, with time allowed to dismount the bars and rechalk the hands if desired.

For all filming sessions a Photo-Sonics 1PL 16mm camera was placed perpendicular to the sagittal plane of the action thirteen meters from the center of the rails. The camera was powered with a portable battery pack. A 16mm Angenieux

12-120mm zoom lens, f16 - f2.2 was mounted on the camera. A Photo-Sonics Timing Light Generator system was hooked up to the camera for the purpose of marking the film with a spot of light at 10Hz intervals (0.1 seconds). This system insures exact measurement of film transport speeds. The camera was loaded with Kodak Ektachrome 7250 EF Color Tungsten light film, ASA 400.

Stroboscopic techniques were used to calibrate the camera's shutter speed prior to filming. The action was filmed with the camera set at 100 frames per second. Shutter angles and exposure times were calculated according to the available light to allow for a minimum exposure time of 1/220 second. Light was measured with a Pentax Spot Meter. Three 28cm reference measures were placed on the supports of the high bar to be used in obtaining a conversion factor. Appendix A contains the specific data of filming and camera settings.

DATA ANALYSIS PROCEDURES

The Cartesian (rectangular) co-ordinates for each of the 21 segmental endpoints and the X and Y co-ordinates of the rail on which the Stalder was performed were obtained for each frame of the film analyzed. A Triad VR/100 pin registered film analyzer was used to project the film images onto a Bendix Platen (model 9864A). The image was aligned with the internal axes of the board to reduce errors in obtaining digitized points. The Bendix Platen was

interfaced to a Hewlett Packard HP9825A desk top computer through a Hewlett Packard HP9864A Digitizer. The system allowed obtaining Cartesian co-ordinates accurate to .036 cm. Co-ordinate points were recorded on a cassett-type magnetic tape mounted within the HP9825A for permanent record. Programs written to reduce data points to useable form were executed on the HP9825A mini-computer in the Biomechanics Laboratory at the University of Alberta. M.I.T. Humanscale data for females were used in the determining of body segment parameters and the location of the total body center of mass in all appropriate computer programs.

The purpose of the study was to statistically analyze differences between Stalder performances as well as carry out a biomechanical analysis. Therefore, the frames selected for analysis were chosen for two purposes: (1) to obtain information which would produce a complete kinematic and kinetic analysis of the Stalder and (2) which would get information on specific actions within the movement so that any statistical differences revealed among performances could be used to pin-point exact performance variations. Twenty two frames were selected for analysis.

The 22 frames examined for each subject were:

(1) Highest Cast Position (Straight Body)
(2) +20 Frames
(3) First Forward Hip Motion
(4) Legs Parallel to Floor
(5) Legs Perpendicular to Floor
(6) Hips at Level of High Bar
(7) Next Frame
(8) Next Frame
(9) Arms Parallel to Floor
(10) -5 Frames from Hips Below High Bar
(11) Hips Below High Bar
(12) Next Frame
(13) Next Frame
(14) Arms Perpendicular to Floor
(15) First Hip Extension
(16) Hips at Level of High Bar
(17) Next Frame
(18) Next Frame
(19) Arms Parallel to Floor
(20) Legs Parallel to Floor
(21) Full Shoulder Flexion (or Hip Extension)
(22) Full Hip Extension (or Shoulder Flexion)

The frames chosen for analysis were selected partially for the purpose of analyzing phases of the skill execution as well as the total Stalder action. Seven phases of skill execution were identified as:

(1) Highest cast position to a position with the hips level to the high bar on the down swing.

(2) Passing the high bar on the down swing.

(3) Passing the high bar on the down swing to hips below the high bar.

(4) Passing below the high bar.

(5) Passing below the high bar to hips level with the

high bar on the up swing.

(6) Passing the high bar on the up swing.

(7) Passing the high bar on the up swing to the final handstand position.

For the purpose of a complete analysis of the Stalder one dependent and 33 independent variables were identified as being critical for the complete analysis. The judges ranking of the trials from best to poorest performance was used as the dependent variable. Five of the independent variables: the gymnasts' mass, height, active shoulder and hip flexibility measures, and mean grip strength were obtained through direct measurement prior to film data collection. Upper extremity, lower extremity, and trunk lengths were obtained from the measurements on the film. The remaining variables were calculated or obtained by combining variables from the raw data and are identified below.

Temporal Data. The total amount of time taken to complete the entire skill as well as the time of the down swing, up swing, and each of the seven phases was determined.

Angular Displacement. The total angular displacement of the center of mass about the rail for each Stalder, as well as for the down swing, up swing, and each of the seven phases was calculated.

Angular Velocity. The average angular velocity for the center of mass about the rail (Wr) and for the gymnast about her own center of mass (Wcm) was calculated for the total skill and all skill phases from the temporal and displacement data.

Shoulder Angles and Range of Motion. The angle formed between the trunk and the upper extremity for all frames analyzed was measured. The total range of motion for each trial was determined as well as the average angle and range of motion during each of the phases.

Hip Angles and Range of Motion. The angle formed between the trunk and the lower extremity for all frames analyzed was measured. The total range of motion for each trial was determined as well as the average angle and range of motion during each phase.

Moment of Inertia. The resistance to turning forces about the rail (Ir) and about the center of mass (Icm) for each frame analyzed was computed using the equation:

$$Ir = \Sigma\, m_i r_i^2$$

where: Ir= the moment of inertia of the gymnast about a transverse axis through the rail.
mi= the mass of the ith segment
r_i^2 = the radius of rotation of the ith segment about the axis of rotation.

The average moment of inertia for all phases were also obtained.

Angular Momentum. The angular momentum about the rail (Hr) and about the gymnast's center of mass (Hcm) between each frame analyzed and an average value for all phases was determined. Angular momentum was computed as:

$$Hr = \Sigma Ii\ \omega i$$

where: Hr = the total angular momentum of the gymnast about the rail.
Ii = the moment of inertia of the ith segment about the rail.
ωi = the angular velocity of the ith segment with respect to the axis of rotation.

Energy. The changes in potential and kinetic energy of the gymnast circling about the rail were computed between each frame for the total skill. Gravitational potential energy was computed from the equation mgh. Total kinetic energy (T) for the system was obtained by summing the translational and rotational kinetic energy of the gymnast about the rail utilizing the total local angular momentum of the body segments and the remote angular momentum of the system about a transverse axis through the rail using the following equations:

Translational kinetic energy

$$T(t) = \Sigma\, 1/2mi(Vxi^2 + Vyi^2)$$

where: mi = the mass of the ith segment
Vxi and Vyi = the horizontal and vertical velocities of the segmental centers of mass between frames x and x+1, respectively.

Rotational kinetic energy

$$T(r) = \Sigma\, 1/2\ Ii\ \omega i^2$$

where: Ii = the moment of inertia of the ith segment about a transverse axis through the segmental center of mass.

ωi = the angular velocity of the segment between frames x and x+1.

Total kinetic energy

$$T = \Sigma\, 1/2\ mi(Vxi^2 + Vyi^2) + 1/2 Ii\ \omega i^2$$

Deflections of the Rail. X, Y, and linear deflections of the rail were measured in each frame from the digitized point of the rail. The materials and construction of a regulation rail are used to insure complete elasticity of the bar.

Forces against the Rail. Forces produced to deflect the rail during the bottom swing were obtained through indirect force measurements from cinematographic data using the equation:

$$a_n = V^2/r + G \cos \theta$$

where: V^2/r = the linear velocity divided by the radius of rotation.

$G \cos \theta$ = mass of the gymnast times the cosine of the angle between the vertical and the radius of rotation.

JUDGING PANEL AND TRIAL RANKING

A panel of gymnastics judges was formed for the purpose

of subjectively evaluating the filmed Stalders and rank ordering the trials. This was done for the purpose of placing trials into groups for statistical analysis of the data.

The trials were consecutively numbered from one to 28 in the order they were filmed. These trial numbers were then randomly drawn for the purpose of editing the film and placing the filmed trials in a random order. Same subject trials were separated by at least two other performances. The edited film was then renumbered from one to 28 and used as the film shown to the judging panel.

The panel was made up of nine experienced gymnastics officials. The highest rated judge held an International rating under the Canadian Gymnastics Federation/F.I.G. rating system and had been a rated official for ten years. Seven of the nine judges held ratings of Provincial or National Judge under the C.G.F./ F.I.G. rating system. All had judged for a minimum of six years with the most experienced having judged for eleven years. The least experienced member of the panel was rated at a Regional level and had three years of gymnastics judging experience.

The judges were instructed to rank the filmed Stalders from best to poorest performance as the trials related to each other. The judges made no attempt to arrive at a score for the Stalders. No instructions were given as to what to look for or how to evaluate the performances. Judges used

their own subjective evaluation and judging experience to compare trials for ranking. They were allowed to view the film as many times as they needed in order to rank the trials to their satisfaction. In all cases, rank ordering by each panel member was arrived at independently. The judges were not present during the filming sessions and saw only the filmed trials.

An overall ranking was made by summing the individual judges rankings for each trial. The sums were then ordered to determine the final ranking. From the judges rankings the trials were divided into four groups each containing seven trials. This division was undertaken for the purpose of carrying out a one way analysis of variance between the groups.

The Stalders ranked highly were considered to be excellent performances according to the subjective evaluation of the judging panel. The trials ranked in the lower part of the ranking were considered to be fair to poor examples of Stalder performance when compared to the higher ranked trials. The final ranking for the trials became the dependent variable for certain statistical investigations.

STATISTICAL PROCEDURES

The statistical procedures were selected in an attempt to obtain information which would reveal differences between the groups as well as the relationships among the selected

variables. Statistics on the data were run utilizing preprogrammed statistical packages prepared by the Division of Educational Research at the University of Alberta. The program package was called XDER. The specific XDER programs were selected for their treatment of the data. The preliminary analyses were performed on all trials for subject-specific and total skill variables; time, displacement and angular velocity for all phases of skill execution; and kinetic variables for Phases 2, 4, and 6. The results from this analysis indicated sufficient differences between Group I and Group IV to support carrying out a more specific analysis of these trials. Kinetic variables and certain performance differences were again analyzed for the total Stalder and for all phases of skill execution for the trials in these groups.

One program used was XDER:DEST02. The description of this program includes the following: "This program calculates means, variances, standard deviations, covariances and correlation coefficients for a maximum of 175 variables. The correlations may be tested for significance. File output of covariances and correlations is also available (XDER package, Hunka, 1979)." Pearson Product Moment Correlation coefficients of the dependent and independent variables for all trials were calculated through the use of the computer program XDER:DEST02. t tests were also run within the same program to determine the significance of the correlation coefficients.

The other XDER program used was XDER:ANOV16. "This program carries out a standard one-way analysis of variance on up to twenty variables with or without equal sample sizes in each group. A fixed effect model is used. The program also provides a test of homogeneity of variance, and pairwise contrasts of means using the Scheffe and Newman-Keuls procedures if the number of groups is 10 or less. Data may be ordered by group membership, or group membership can be identified on data cards (XDER package, Hunka, 1979)." From the judges' rankings four performance groups were identified. The performances of the groups were compared through a one-way analysis of variance using the program XDER:ANOV16. In cases where a significant difference of at least a .05 level of significance was obtained, a Scheffe contrast between Group I and Group IV was carried out. The subject composition of the groups and the judges' evaluations of the general performance of these groups support that contrasts between Group I and Group IV be undertaken.

CHAPTER IV

ANALYSIS OF DATA AND DISCUSSION OF RESULTS

INTRODUCTION

The study was carried out utilizing 14 Class I and Elite level gymnasts from Canada and the United States. The composition of the optional uneven parallel bars routine for the 1980 competitive season of ten of the subjects contained at least one Stalder element. Of the remaining four subjects, two had Endo (forward Stalder action with a reverse grip) elements in their optional routines. The Elite gymnasts had all competed the 1980 Compulsory uneven parallel bars routine which contained a Stalder element as well. All 28 trials were performed with sufficient technical execution to have been awarded 'B' or 'C' difficulty credit in a competitive situation with a similar performance (see Appendix D). However, specific deductions in execution/amplitude (See Appendix C) could have been taken in all trials according to the judging panel.

Respecting the definition of various Stalder types presented in the literature, all subjects performed an early straddle-in technique in both trials. From the information obtained through the mechanical and statistical analyses of these Stalders, certain similarities and significant differences were obtained between the highest and lowest ranked groups. The similarity in performance technique

along with the differences revealed, set the basis for presentation of data analysis in this chapter.

One trial was selected from Group I and one from Group IV for specific presentation of the data. This procedure was undertaken for the purpose of analyzing an actual performance from each group rather than an artificial trial composed of the means of all the variables within each group. Selection of the specific trials to be used for presentation was made following the complete biomechanical and statistical analysis of all trials. The trials selected for presentation were chosen due to their rank position within their groups and the similarity between the specific variables and the group means for the majority of those variables. Subject JM, Trial 2, was selected from Group I. This trial was ranked fourth in Group I as well as fourth overall. Subject AD, Trial 1, was chosen from Group IV. This trial was also ranked fourth within the group and twenty-fifth overall.

This chapter is organized and presented under the following headings: (1) Subject-Specific Data, (2) Analysis of Data, (3) Statistical Analysis of Data, (4) Discussion

SUBJECT-SPECIFIC DATA

Prior to filming sessions and from the filmed Stalders certain measurements were taken on each subject. Information on competitive experience, vital statistics, and

anthropometric measures were obtained to help determine differences among subjects. The personal and anthropometric measurements of JM and AD are presented in Table 1. Appendices E and F contain these measures for all subjects.

Table 1. Subject- Specific Variables Subjects For JM and AD

SUBJECT:	JM	AD
VARIABLES		
Years in Competition	3	2
Years Class I+	2.5	.1
Age (years)	14.5	11.5
Mass (wt. in Kg)	38.56	26.76
Height (cm)	147.32	129.54
Upper Extremity Length (cm)	46.50	39.68
Trunk Length (cm)	49.53	40.02
Lower Extremity Length (cm)	63.21	60.19
$\bar{x}$ Grip Strength (kg)	17.63	10.34
Active Shoulder Flexibility (rads)	3.39	3.49
Active Hip Flexibility (rads)	3.06	3.17

ANALYSIS OF DATA

Temporal Data

The frame designated 'frame 1' for each trial corresponded to the first analyzed frame - the highest cast position. The actual frame number of the film relative to the 22 analyzed frames are contained in Table 2. Total time of the Stalder was taken from the first position analyzed, the initial highest cast, to the final position of greatest shoulder flexion and hip extension.

Table 2. Actual Frame Numbers of Analyzed Frames.

SUBJECT/ TRIAL	1	2	3	4	5	6	7	8	9	10	11
	SELECTED FRAMES										
	ACTUAL FRAME										
YW2	1	21	45	53	82	95	96	97	101	117	122
TT2	1	21	43	47	67	82	83	84	90	106	111
YW1	1	21	33	40	66	78	79	80	84	99	104
JM2	1	21	91	97	119	131	132	133	139	151	156
JM1	1	21	61	68	90	103	104	105	111	124	129
DW2	1	21	86	91	123	136	137	138	144	155	160
TT1	1	21	46	48	67	83	84	85	90	106	111
DW1	1	21	64	66	96	113	114	115	121	132	137
NG2	1	21	61	68	89	104	105	106	112	121	126
KK2	1	21	45	76	100	112	113	114	121	133	138
NG1	1	21	35	53	78	92	93	94	100	108	113
KK1	1	21	57	77	101	113	114	115	122	135	140
CH2	1	21	48	90	109	123	124	125	130	140	145
TQ2	1	21	54	66	90	108	109	110	117	129	134
LW2	1	21	41	50	86	117	118	119	126	141	146
YM1	1	21	57	61	87	105	106	107	112	125	130
TQ1	1	21	39	44	68	86	87	88	95	106	111
JF1	1	21	33	35	59	85	86	87	97	104	109
YM2	1	21	41	54	80	96	97	98	102	116	121
CH1	1	21	85	97	122	136	137	138	144	154	159
LW1	1	21	31	70	111	143	144	145	153	167	172
JL1	1	3	21	56	80	113	114	115	126	138	143
JF2	1	21	29	33	55	81	82	83	92	100	105
JB1	1	21	85	91	117	135	136	137	143	153	159
AD1	1	11	21	39	52	76	77	78	87	94	99
JB2	1	21	50	53	76	96	97	98	104	115	120
AD2	1	21	48	54	85	111	112	113	122	128	133
JL2	1	5	21	44	73	107	108	109	120	133	138

Table 2. (Continued)

SUBJECT/ TRIAL	SELECTED FRAMES 12	13	14	15	16	17	18	19	20	21	22
	ACTUAL FRAMES										
YW2	123	124	127	137	148	149	150	159	171	209	221
TT2	112	113	117	134	138	139	140	147	181	194	223
YW1	105	106	109	124	130	131	132	141	150	197	201
JM2	157	158	162	168	180	181	182	191	193	224	234
JM1	130	131	135	143	152	153	154	163	166	196	214
DW2	161	162	167	174	182	183	184	193	205	231	247
TT1	112	113	117	134	137	138	139	145	184	191	218
DW1	138	139	143	153	160	161	162	170	179	205	227
NG2	127	128	133	140	140	150	151	162	170	220	223
KK2	139	140	145	155	166	167	168	174	181	197	246
NG1	114	115	121	128	137	138	139	150	158	204	210
KK1	141	142	147	156	168	169	170	180	187	226	261
CH2	146	147	152	159	168	169	170	181	182	202	246
TQ2	135	136	140	150	159	160	161	171	188	232	252
LW2	147	148	152	161	170	171	172	184	185	243	250
YM1	131	132	136	152	153	154	155	164	167	181	214
TQ1	112	113	118	129	136	137	138	147	164	204	209
JF1	110	111	119	124	133	134	135	147	149	189	215
YM2	122	123	126	140	144	145	146	157	158	173	213
CH1	160	161	166	176	181	182	183	194	198	219	264
LW1	173	174	179	190	197	198	199	210	211	276	286
JL1	144	145	152	155	167	168	169	182	196	287	300
JF2	106	107	115	120	129	130	131	142	146	167	218
JB1	159	160	165	172	180	181	182	191	197	258	259
AD1	100	101	109	113	123	124	125	134	153	195	214
JB2	121	122	127	135	141	142	143	153	166	207	226
AD2	134	135	143	149	157	158	159	171	190	232	239
JL2	139	140	147	152	161	162	163	177	185	242	247

Subject JM completed the total action in 2.45 seconds. Subject AD completed her Stalder in 2.24 seconds. Temporal data for the total skill, the down swing and the up swing are presented in Table 3.

Table 3. Temporal Data for Total Skill, Down Swing, and Up Swing in Seconds

	ALL TRIALS	GROUP I	GROUP IV
TOTAL SKILL			
RANGE	2.09 - 3.14	2.09 - 2.78	2.24 - 3.14
MEAN	2.48	2.40	2.58
S.D.	.07	.05	.09
DOWN SWING			
RANGE	1.03 - 1.69	1.10 - 1.69	1.03 - 1.65
MEAN	1.36	1.34	1.37
S.D.	.04	.05	.05
UP SWING			
RANGE	.82 - 1.65	.82 - 1.23	1.11 - 1.65
MEAN	1.12	1.01	1.25
S.D.	.03	.02	.04

Temporal data for the seven phases of skill execution show similar times between JM and AD except during the straddle-in action (Phase 1) and the end of the straddle-out action (Phase 7). JM took 1.37 seconds to complete the straddle-in action in her Stalder. AD took .79 seconds to complete the same action. Time differences for the straddle-out action were reversed as AD used .96 seconds to achieve the final position from the point at which the hips were level with the rail on the up swing. JM took .57 seconds to complete this action. The time of each phase for JM and AD are listed in Table 4.

Table 4. Temporal Data for the Seven Phases of Skill Execution for Subjects JM and AD

SUBJECT	PHASES 1	2	3	4	5	6	7
JM	1.37	.02	.26	.02	.25	.02	.57
AD	.97	.02	.24	.02	.25	.02	.96

Displacement of the Center of Mass about the Rail

Performance differences between subjects occurred due to the position of the body in the initial highest cast and the point in the up swing when attainment of the final position was achieved. Common differences between JM and AD in the starting and ending positions are illustrated in Figures 1 and 2. JM began and ended the Stalder in a handstand position and rotated through 6.12 radians (350.65 degrees) from the initial highest cast to the final handstand. AD, beginning in a position parallel to the floor and ending above the rail in an extended position, rotated through 5.94 radians (340.34 degrees) for the total skill. The similarity among all trials for displacement of the center of mass about the rail can be noted from the data in Table 5.

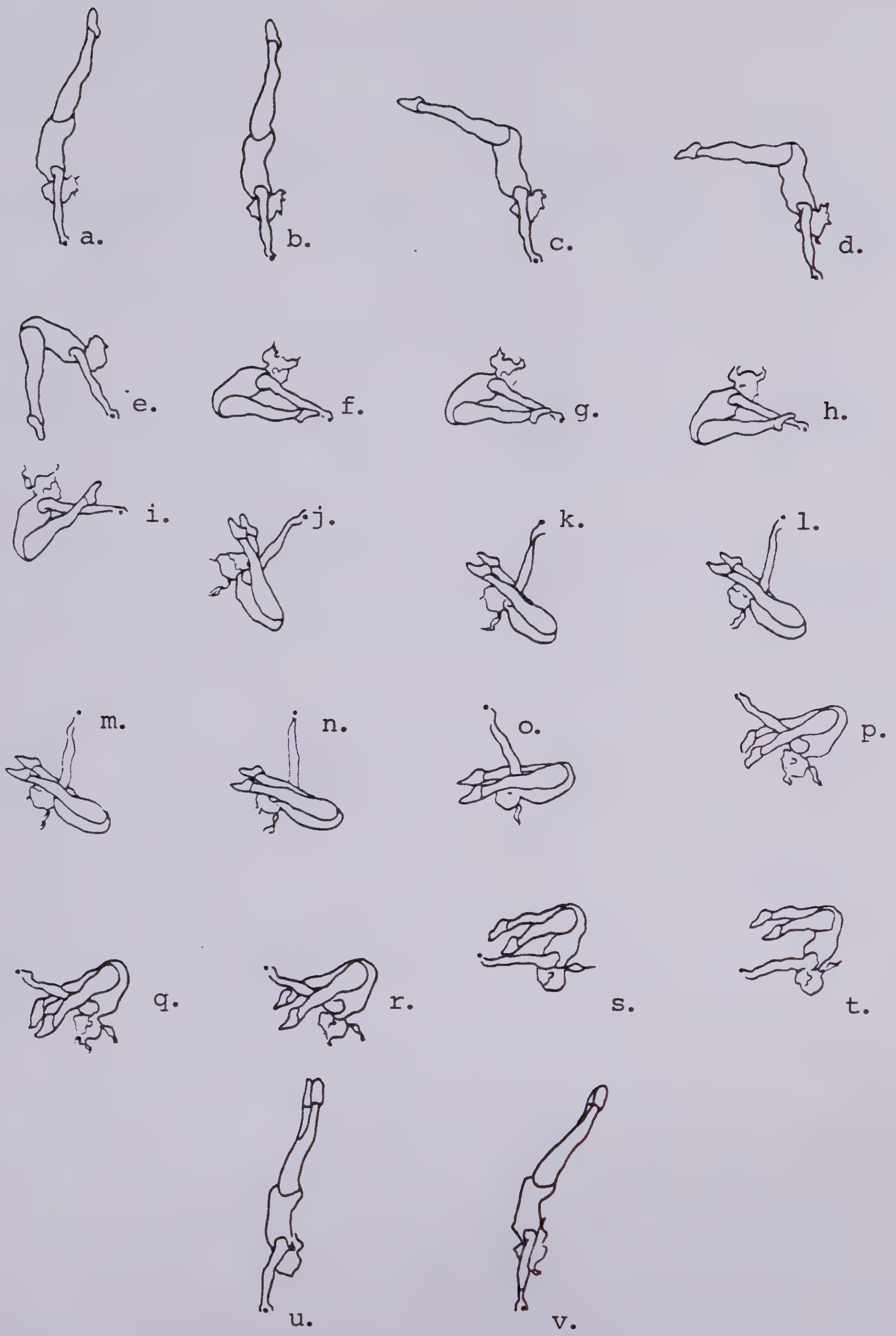

Figure 1. Tracings of Analyzed Frames For Total Stalder Performance for Subject JM.

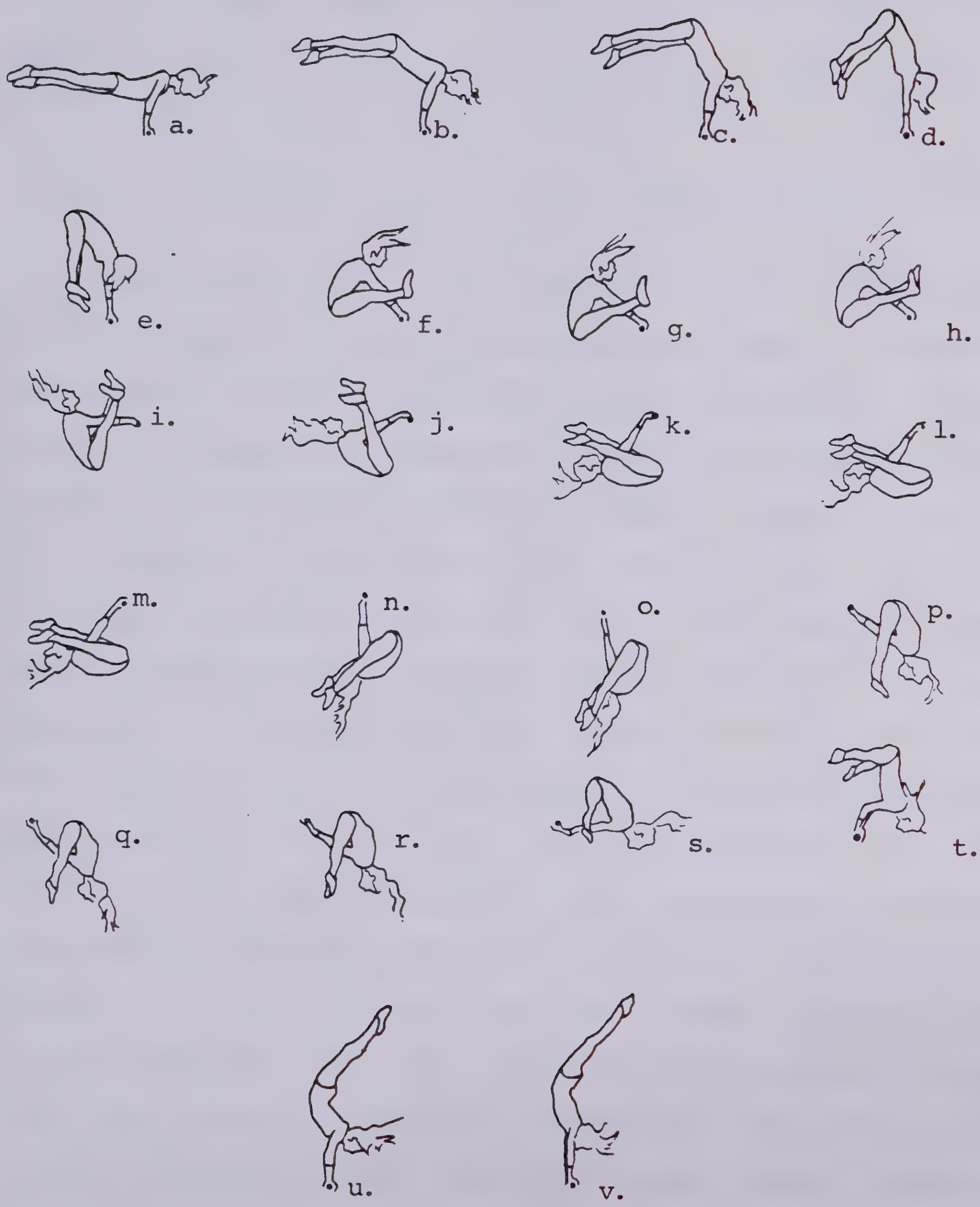

Figure 2. Tracings of Analyzed Frames For Total Stalder Performance for Subject AD.

Table 5. Total Displacement of the Center of Mass About the Rail in Radians For All Trials

	ALL TRIALS	GROUP I	GROUP IV
RANGE	5.56 - 6.63	6.02 - 6.29	5.56 - 6.63
MEAN	6.07	6.11	6.02
S.D.	.25	.11	.35

Displacement of the center of mass during the straddle-in action (Phase 1) encompassing frames 1-6 shows a considerably varied pattern between the two gymnasts. JM's center of mass was displaced through 1.35 radians (77.35 degrees) in the direction of the Stalder in Phase 1. (Fig. 3). Figure 4 is a plot of the location of the center of mass about the rail for the total skill. The center of mass was displaced through a fairly smooth, oval path. The amplitude of the down swing was similar to the up swing as the average distance between the center of mass and the rail while passing it on the down swing was 57.68cm and the radius while passing the rail on the up swing was 59.18cm. AD's center of mass was displaced through .74 radians (42.40 degrees) in the direction of the Stalder during the straddle-in phase (Fig. 5). The path of AD's center of mass about the rail is plotted in Figure 6. The path is not smooth indicating body position changes which greatly affected the center of mass. Although, the radius of rotation of the center of mass about the rail was approximately 34.0cm as AD passed the bar on both sides, the

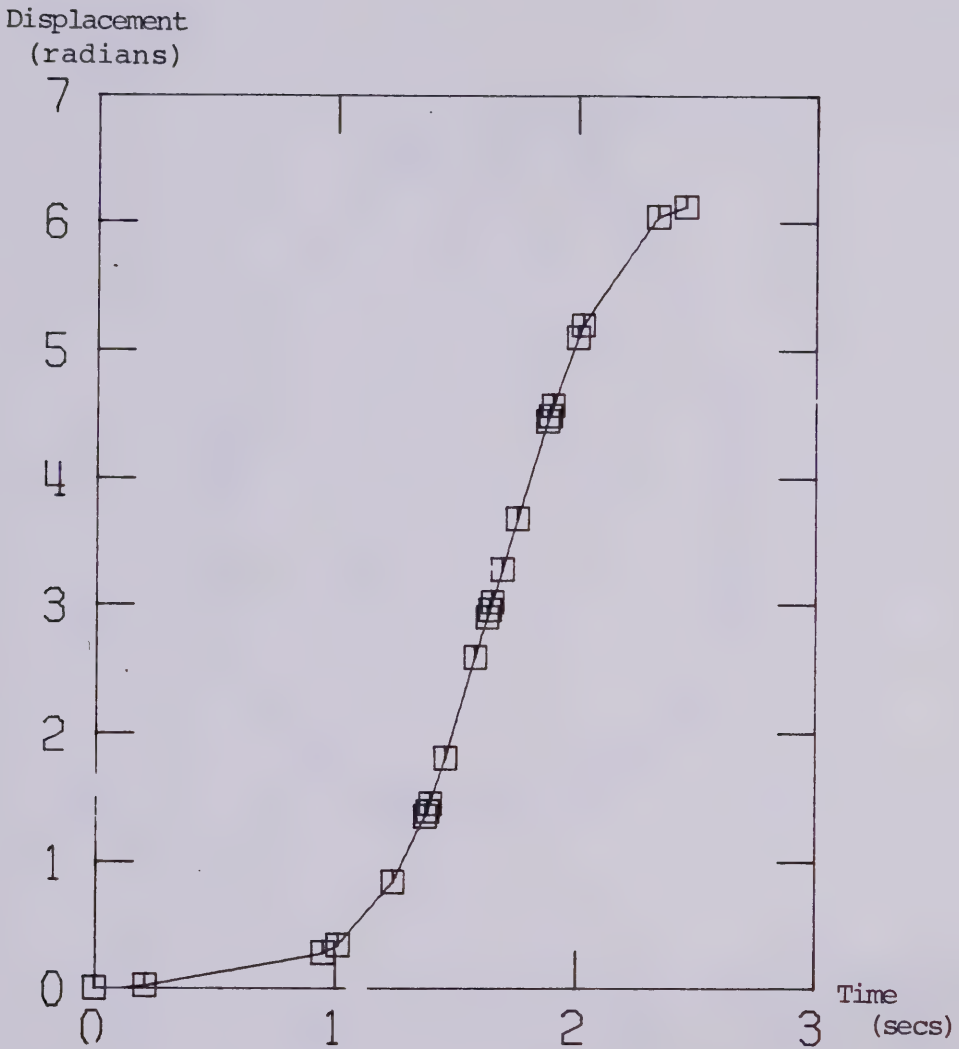

Figure 3. Displacement of the Center of Mass for Subject JM.

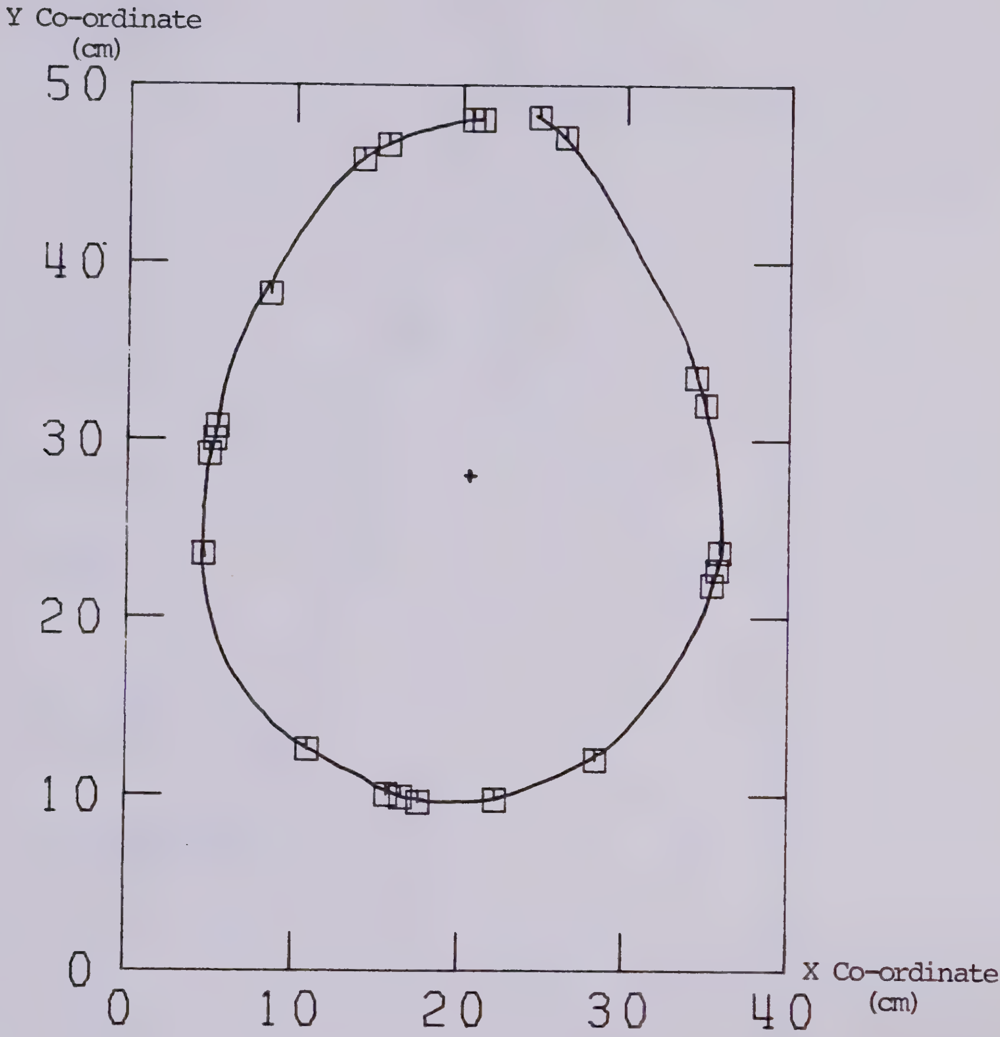

Figure 4. X Y Plot of Center of Mass for Subject JM.

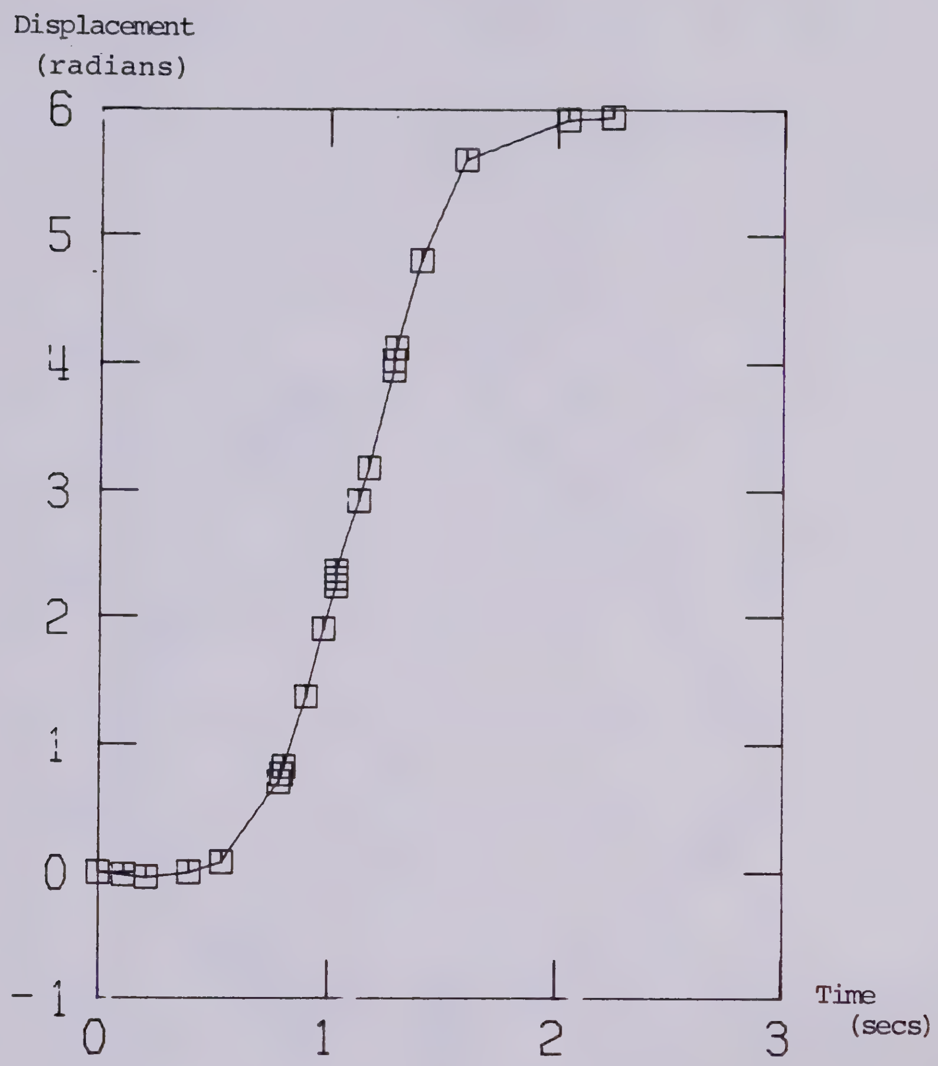

Figure 5. Displacement of the Center of Mass for Subject AD.

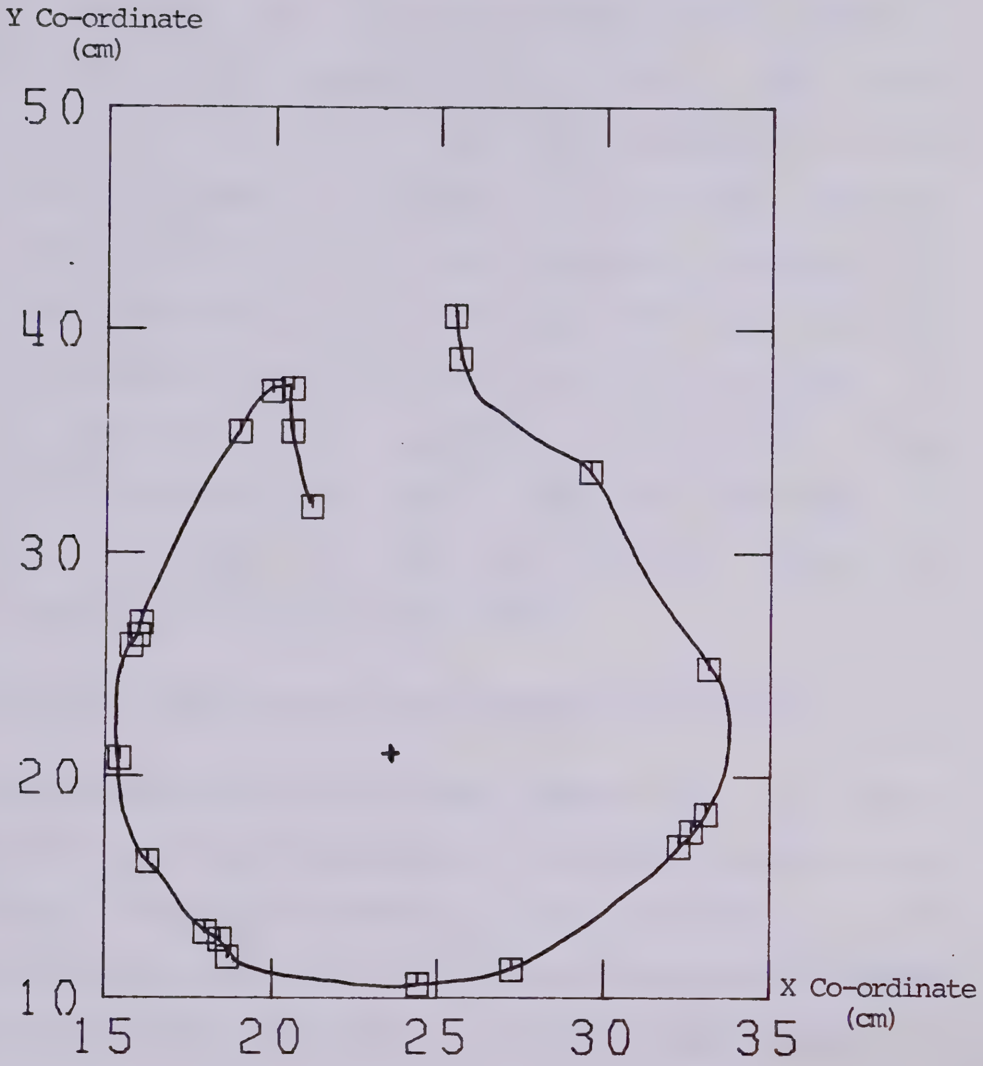

Figure 6. X Y Plot of Center of Mass for Subject AD.

path was different.

JM's initial highest cast position (Fig. 1a) was to a handstand above the rail. All displacement of the center of mass was positive with respect to the skill. AD casted initially to a position in which the shoulders were above the rail but the body was horizontal to the floor. Flexion of the arms at the shoulders caused the center of mass to be raised and displaced to a position above the shoulders. However, this action produced displacement of the center of mass in a line of direction opposite to the desired circling action of the Stalder (Fig. 2a-d). Positive displacement of AD's center of mass did not occur until .54 seconds had passed from the beginning of the skill.

Articular Displacements and Moments of Inertia

Internal amplitude differences caused by the varying amounts of shoulder extension and hip flexion had a direct influence on kinetic variables. The amplitude of the initial highest cast placed the gymnast in a position which would directly affect the radius of rotation, moments of inertia and measures of angular momentum about the rail and about the gymnasts' own center of mass. Initial measures of gravitational potential energy were determined at this point. The initial highest cast position also had an affect on the amount of kinetic energy potentially available.

JM at the highest cast position (Fig. 1a) had achieved

an upper extremity/trunk angle of 3.15 radians (180.67 degrees) of shoulder flexion and .36 radians (20.85 degrees) of hyperextension of the lower extremity to the trunk. This position produced a measure of 27.13 Kg.m2 for the moment of inertia (Ir), 4.13 Kg.m2 for the moment of inertia (Icm) and a potential energy measure of 543.22J at the start of the Stalder. Due to the extended handstand position above the rail which was JM's initial highest cast, these measures are close to the maximum that JM could produce. Thus, JM began the Stalder in a position to generate optimum measures of angular momentum (Hr) and kinetic energy (T) in the down swing. The maximizing of these variables in the down swing was necessary for achieving maximum amplitude in the up swing.

Throughout the Stalder performance JM displaced the upper extremities through 1.47 radians (84.22 degrees) of extension at the shoulder. Change in hip angles measured 3.03 radians (173.61 degrees) of displacement of the lower extremities to the trunk. Considering 180 degrees as full shoulder extension and hip flexion in this action, JM utilized 47% of the total range of motion in shoulder extension and 96% of the total range of motion in hip flexion throughout the skill performance. Shoulder extension was continuous from the beginning of the skill to the completion of the straddle-in action (Phases 1 and 2) (Fig. 7). The position of the upper extremity to the trunk varied slightly in both flexion and extension throughout the

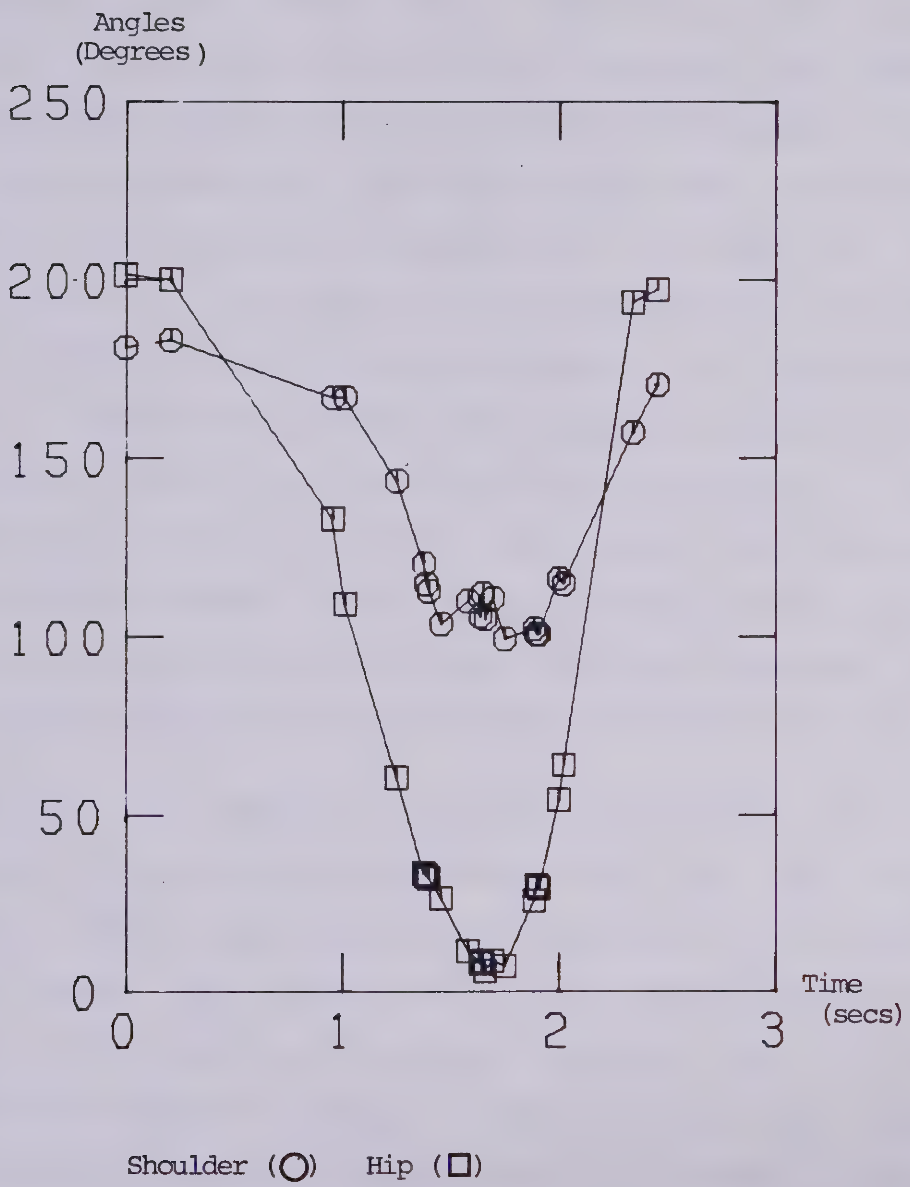

Figure 7. Shoulder and Hip Angles for Subject JM.

entire bottoming action. Continual shoulder flexion to the final position did not begin until the beginning of the straddle-out action (Phase 6). Flexion of the lower extremity to the trunk was continuous throughout the entire down swing and remained somewhat constant as JM passed below the high bar (Phase 4). Extension of the lower extremities at the hip was continual throughout the up swing to the final position. The rates of change of shoulder extension and hip flexion are illustrated in Figure 8, an angle/angle diagram. Displacement of the lower extremity occurred to a much greater extent than that of the upper extremity. The starting and ending positions were similar with shoulder flexion being somewhat less at the completion of the Stalder than at the beginning, but handstand positions indicated by near maximum shoulder flexion and hip extension were shown.

Changes in shoulder and hip angles directly affected the radius of rotation of the gymnast about the rail and, therefore, affected the moment of inertia (Ir). The changes in the moment of inertia follow the general pattern of changes in body position throughout the skill (Fig. 9). The value of the moment of inertia at the outset of the skill when JM was in a handstand position was 27.13 Kg.m2. Moment of inertia (Ir) decreased through the down swing as JM performed the straddle-in to achieve an inverted dorsal hang. The shortening of the radius of rotation caused a decrease in the moment of inertia (Ir) to 13.19 Kg.m2 at the

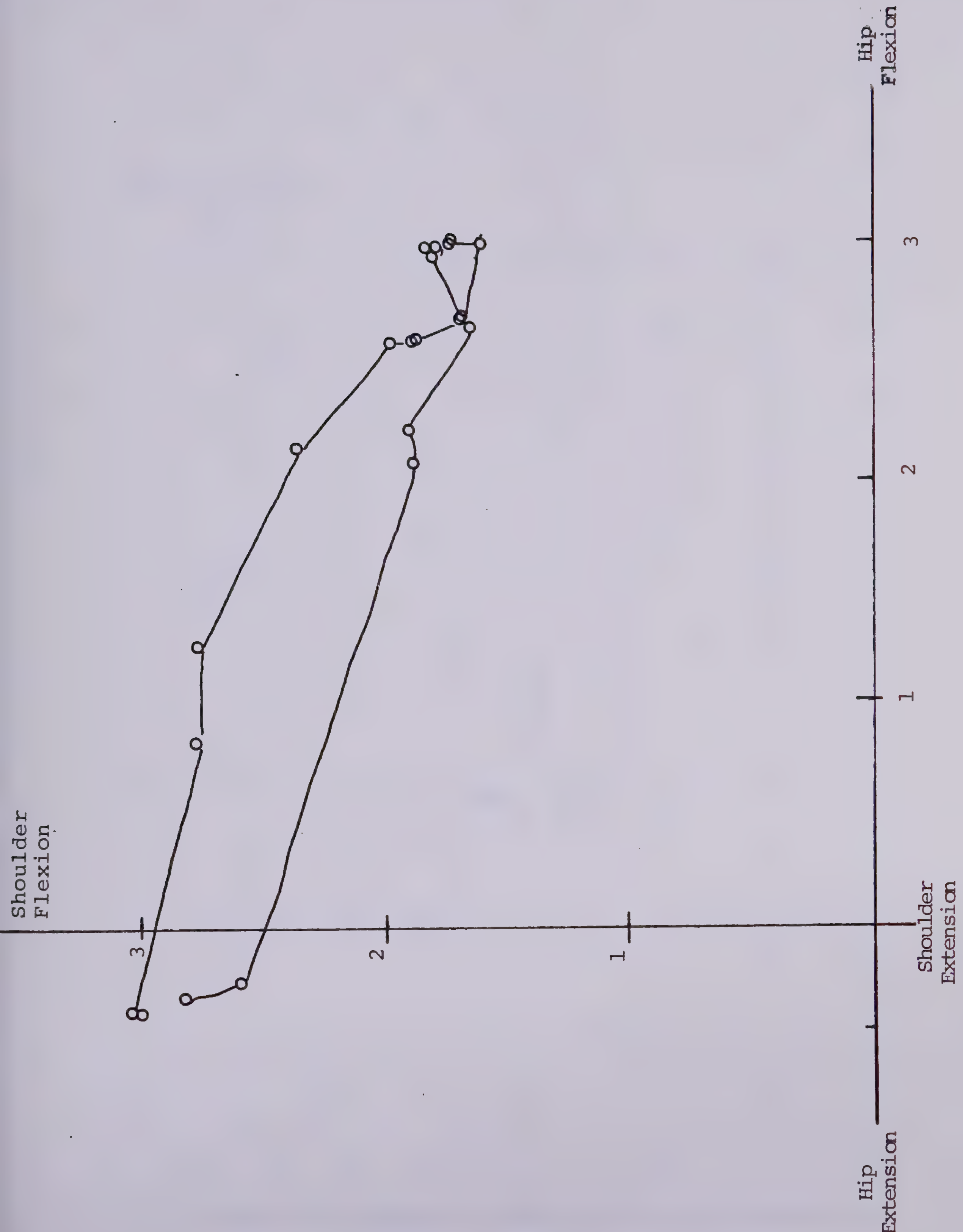

Figure 8. Angle/Angle Diagram in Radians of Shoulder Extension and Hip Flexion for Subject JM.

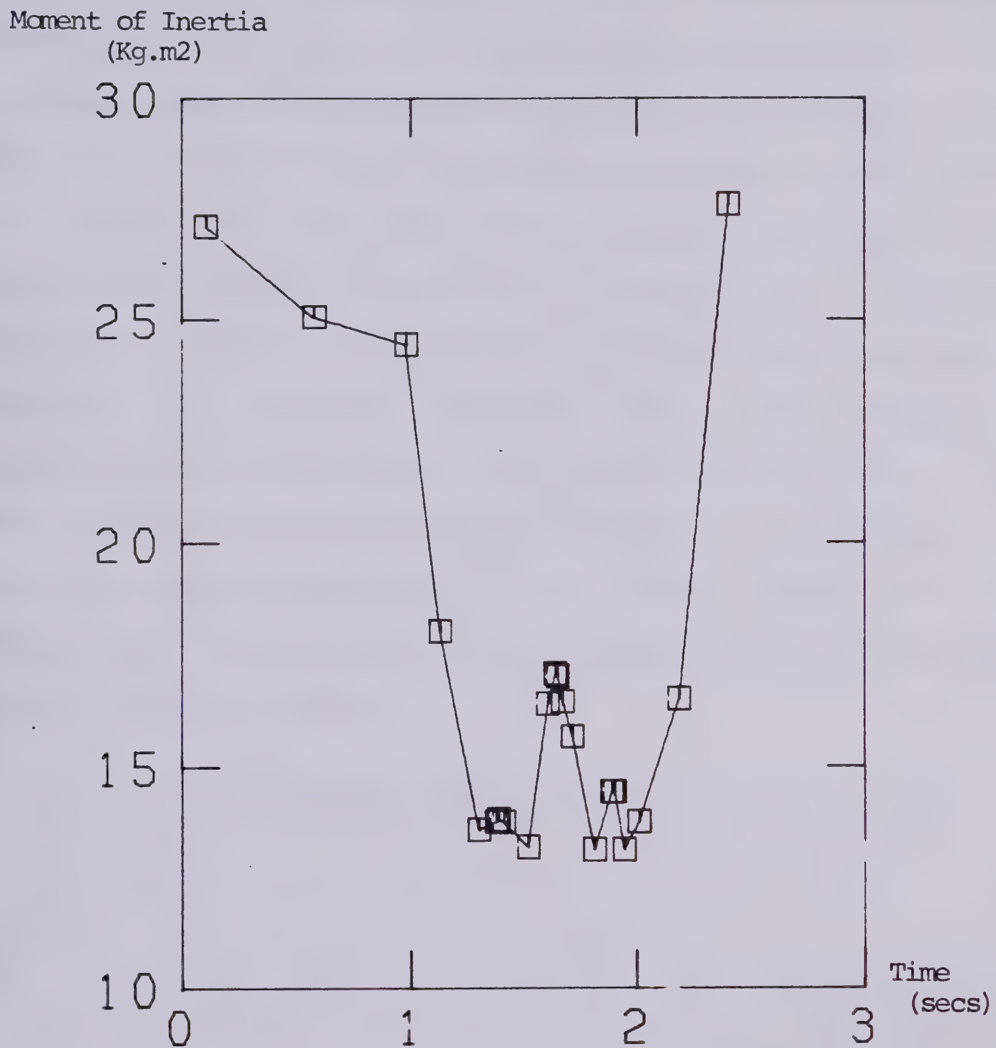

Figure 9. Moments of Inertia (Ir) for Subject JM.

end of the rock back. Through the bottom swing the moment of inertia increased slightly to approximately 17.00 Kg.m2. This increase in the moment of inertia can be attributed to gravity pulling downward on the subject at the point of the greatest angular momentum, and causing some flexion of the upper extremities at the shoulders and enhancing the action of flexion at the hips. Throughout the up swing and the straddle-out action JM worked to return to a handstand position. At the final position JM's position showed 169.77 degrees of shoulder flexion and 16.85 degrees of hyperextension of the lower extremity at the hip (Fig. 1v). This position caused the moment of inertia to increase to a final measure of 27.61Kg.m2. The mean measure for the moments of inertia for the seven phases of skill execution are contained in Table 6.

Table 6. Mean Measures of the Moment of Inertia (Ir) in Kg.m2 for All Phases of Skill Execution for Subject JM

PHASE	1	2	3	4	5	6	7
$\bar{x}$Ir	21.66	13.77	14.18	17.03	15.86	14.43	16.65

Changes in moment of inertia (Ir) were accompanied by changes in the moments of inertia of the body about its own center of mass (Fig. 10). These patterns are very similar. The values for the mean moment of inertia (Icm) for all phases of skill execution presented in Table 7 show that following the initial straddle-in until the beginning of the

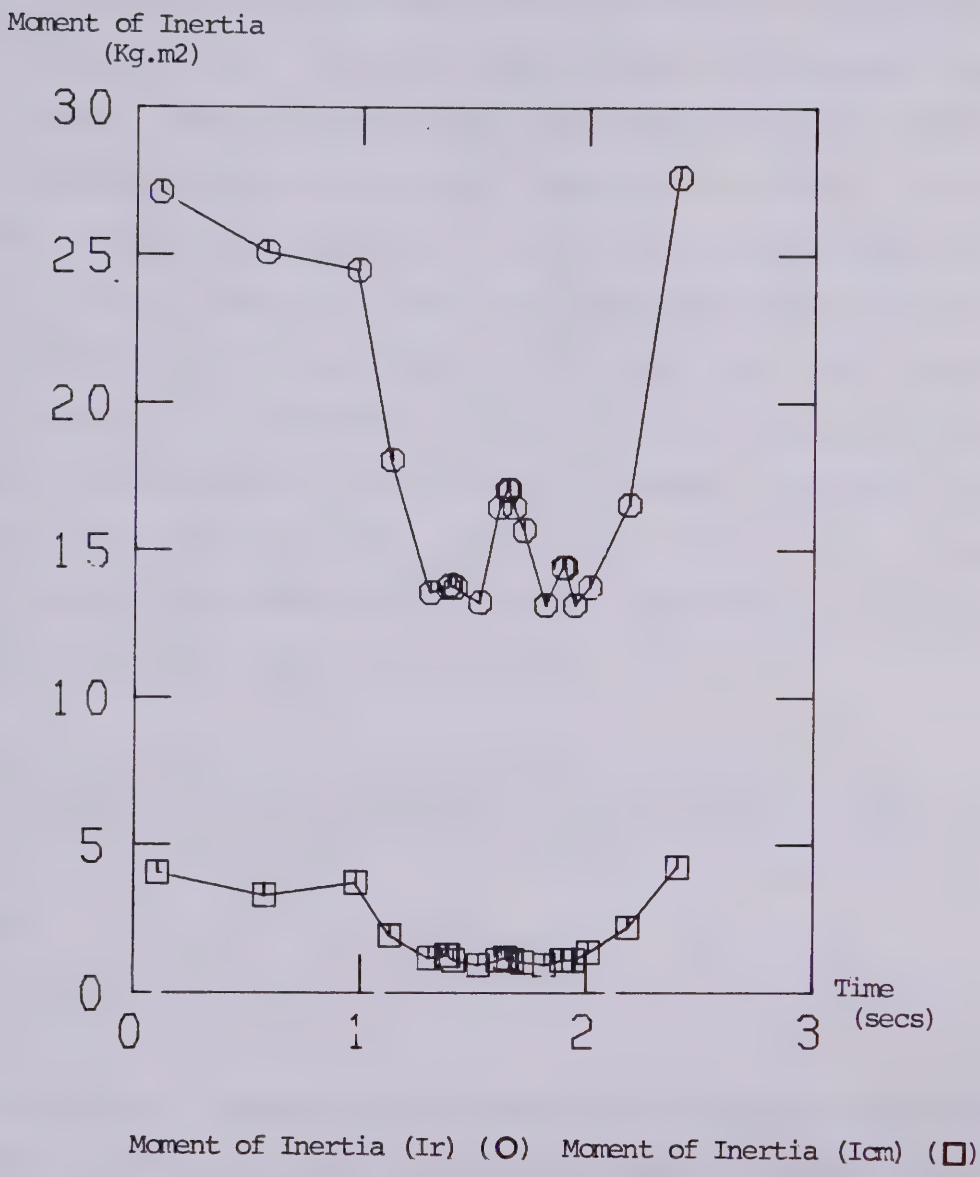

Figure 10. Moments of Inertia (Ir) and Moments of Inertia (Icm) for Subject JM.

straddle-out JM maintain a fairly constant body position ($\bar{x}$Icm = 1.15Kg.m2). Comparison of the changes in shoulder angles to changes in the moment of inertia (Ir) show nearly identical patterns. Changes in the radius of rotation of the gymnast about the rail was most affected by the amount of shoulder extension occurring. This had a strong effect on the moment of inertia (Ir) as well as the moment of inertia (Icm). The body positions displayed by JM were such that the hips were always further from the rail than were the shoulders. The moment of inertia (Icm) was not at the minimum potentially available to JM. Greater measures of moment of inertia (Ir) and moment of inertia (Icm) contributed toward achieving optimum measures of angular momentum (Hr) and kinetic energy (T).

Table 7. Mean Measures of Moments of Inertia (Icm) in Kg.m2 for all Phases of Skill Execution For Subject JM

PHASE	1	2	3	4	5	6	7
$\bar{x}$Icm	2.90	1.32	1.19	1.19	1.10	1.13	1.89

The mean averages for moment of inertia (Icm) for Phases 1 (2.90Kg.m2) and 7 (1.89Kg.m2) appear greater than are the actual differences at the start and ending of the Stalder. At the initial highest cast position JM had an moment of inertia (Icm) of 4.13Kg.m2 and at the completion of the Stalder this variable measured 4.26Kg.m2. The differences in the averages of the two phases can be

attributed to the flexion of the arms at the shoulders preceding the extension of the legs at the hips in the straddle-out. The greater mass of the legs, held in a flexed position would not affect a large change in the moment of inertia (Icm) until extension occurred later in the straddle-out.

The performance technique displayed by AD produced different upper extremity actions, but very similar lower extremity actions to JM's performance. At the initial highest cast position AD had achieved 1.04 radians (59.63 degrees) of flexion at the shoulders and 3.76 radians (176.24 degrees) of extension at the hips. Figure 2a illustrates the internal and external amplitude displayed by AD at the first analyzed frame. This position produced a moment of inertia (Ir) of 7.21 Kg.m2, a moment of inertia (Icm) of 1.85 Kg.m2 and a measure of gravitational potential energy of 217.97J. Rapid shoulder flexion following the initial cast position caused the center of mass to be raised and along with an increase in the shoulder angle produced an increase in the measure of the moment of inertia (Ir) to 10.19 Kg.m2 prior to any forward circling motion of the gymnast.

Throughout the Stalder, AD displaced the upper extremity through 2.08 radians (119.17 degrees) of shoulder extension. This represented 66% of the possible range of motion to achieve full shoulder extension. The change in

hip angle was through 3.06 radians (175.33 degrees) of flexion or 97% of the possible range of motion for the lower extremity. The changes in shoulder and hip angles throughout the Stalder performance by AD are illustrated in Figure 11. Following the initial rapid shoulder flexion at the beginning of the Stalder, AD performed continual shoulder extension throughout the entire down swing and as she passed below the rail to a minimum shoulder angle of 36.91 degrees. Shoulder flexion was performed throughout the entire up swing to a shoulder angle of 173.80 degrees at the final position. This measure was 114.17 degrees greater than the shoulder flexion at the initial highest cast at the beginning of the skill. AD achieved maximum hip extension (35.51 degrees of hyperextension) prior to maximum shoulder flexion at the completion of the skill. This is the reverse pattern for JM.

The angle/angle diagram of AD's joint actions shows rapid hip flexion accompanied by rapid shoulder extension in the down swing (Fig. 12). The up swing is characterized by rapid hip extension followed by shoulder flexion to the final position. The completion of the performance was to a position much closer to a handstand than was the initial position. The moment of inertia (Ir) measured at the final extended position was 12.89 Kg.m2. The final position of the Stalder for AD is illustrated in Figure 2v.

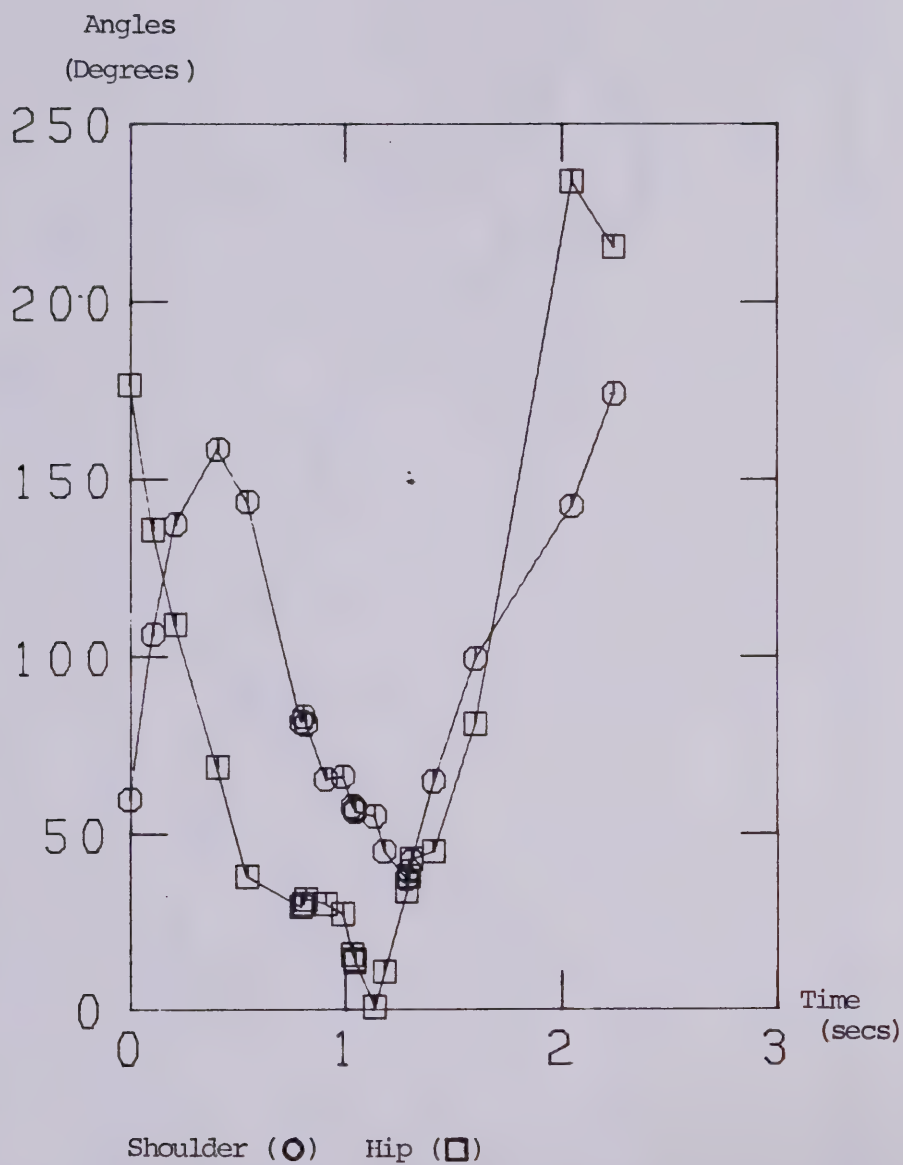

Figure 11. Shoulder and Hip Angles for Subject AD.

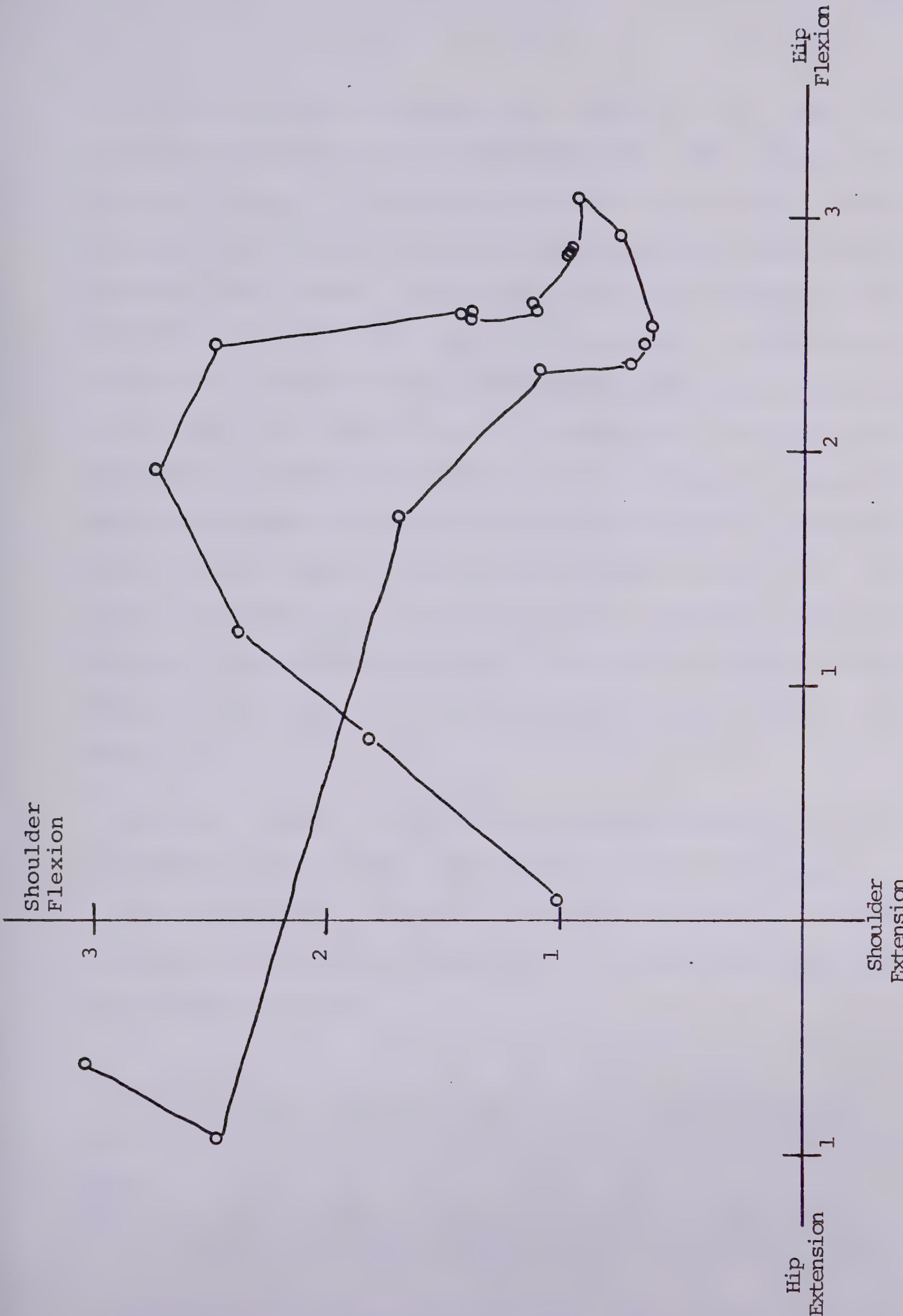

Figure 12. Angle/Angle Diagram in Radians of Shoulder Extension and Hip Flexion for Subject AD.

The measures of moment of inertia (Ir) (Fig. 13) throughout the skill very closely followed the changes in shoulder angles. The initial highest cast position (7.21 Kg.m2) was followed by an increase in shoulder flexion which increased the radius of rotation of the gymnast, and, therefore, caused the moment of inertia to increase to 10.19Kg.m2. The down swing was characterized by a decrease in the moment of inertia (Ir) to 3.10Kg.m2 at the end of the straddle-in action. Through the bottom swing the moment of inertia increased slightly to 4.61 Kg.m2 as gravity enhanced hip flexion by causing the legs to be drawn closer to the trunk and the body rotated through increased shoulder extension to a position in which the legs and shoulders were dropped below the hips thus lengthening the radius of rotation.

As AD worked to return to handstand position at the completion of the skill, the moment of inertia increased to a final measure of 12.89Kg.m2. The mean measures of moment of inertia (Ir) for the seven phases of skill execution are presented in Table 8.

Table 8. Mean Moments of Inertia (Ir) in Kg.m2 for AD

PHASE	1	2	3	4	5	6	7
$\bar{x}$Ir	8.20	3.66	3.49	4.50	4.26	3.67	6.11

Changes in the moment of inertia (Icm) for AD followed

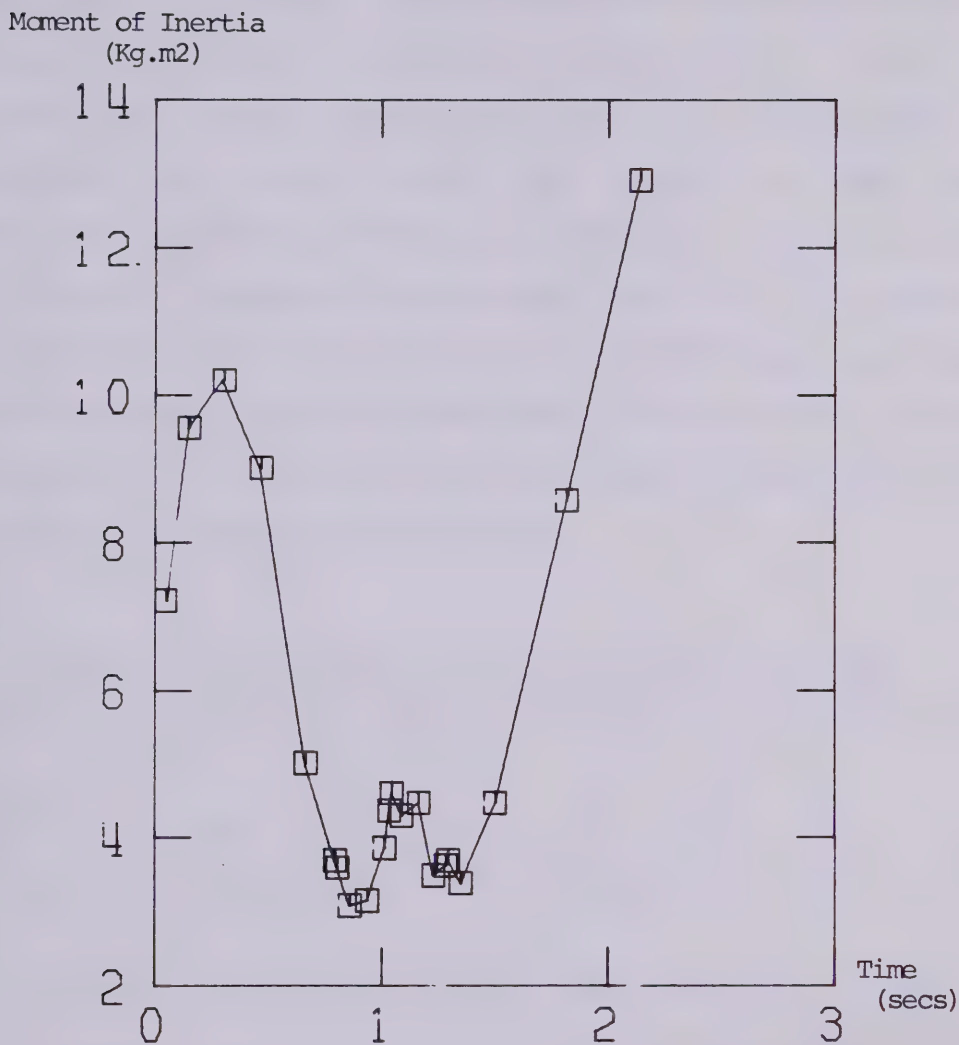

Figure 13. Moments of Inertia (Ir) for Subject AD.

the pattern for the moment of inertia (Ir) (Fig. 14). Due to the larger measures of shoulder extension found for AD throughout the skill, the radius of rotation of her body about its own center of mass was quite small. Once the straddle-in action was accomplished, very little change in the moment of inertia about the center of mass ($\bar{x}$ = .53Kg.m2) occurred as displayed in Table 9. From the amount of shoulder extension performed, AD was in a position throughout most of the Stalder in which her hips were closer to the rail than were her shoulders. This position enhanced rotation of the body about its own center of mass and kept the moment of inertia (Icm) small.

Table 9. Mean Measures of Moment of Inertia (Icm) in Kg.m2 for all Phases of Skill Execution for Subject AD

PHASE	1	2	3	4	5	6	7
$\bar{x}$Icm	1.28	.58	.55	.58	.51	.49	.84

Angular Velocity and Angular Momentum

Gravity acting on the gymnast provided the force which caused the gymnast to circle the rail. Due to the downward acceleration produced by gravity the angular velocity and the angular momentum of the center of mass increased through the down swing and decreased throughout the up swing. Amplitude in body position, producing a large radius of rotation, was needed to maximize these variables.

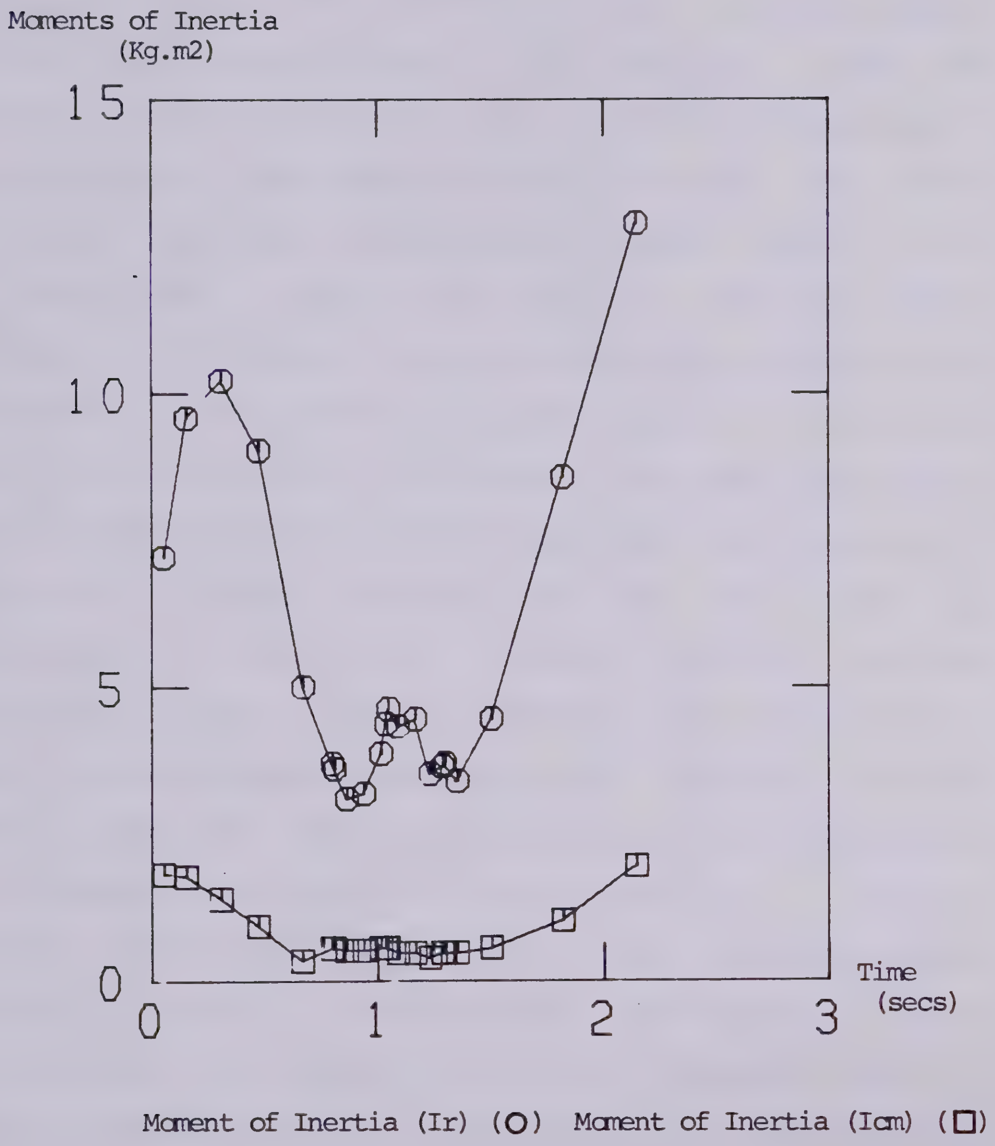

Figure 14. Moments of Inertia (Ir) and Moments of Inertia (Icm) for Subject AD.

JM had an average angular velocity of 2.50 rads/sec throughout the entire Stalder. Her average velocity on the down swing was 1.81 rads/sec and her average angular velocity for the up swing was 3.89 rads/sec. The great angular momentum produced in the down swing enabled JM, by manipulating her body positions, thus changing the body's moment of inertia, to have greater angular velocity in the up swing than in the down swing to conserve angular momentum. The changes in angular velocity produced in the performance of this Stalder are illustrated in Figure 15. Figure 16 is a plot of the smoothed data curve for angular velocity with respect to the average means for the phases of execution. Angular velocity data for all trials are presented in Table 10. Angular velocity increased throughout the down swing. Through the bottom and up swings, two decreases followed by rapid increases in angular velocity occurred. Both of these decreases were accompanied by increases in the moment of inertia (Fig. 17). Changes in shoulder extension showed that some shoulder flexion occurred at frame 12, thus increasing the radius of rotation and, therefore, the moment of inertia. The second drop in angular velocity occurred at frame 17. Again an increase in the moment of inertia, caused by extension of the lower extremity at the hips to initiate the straddle out, caused a drop in angular velocity to conserve angular momentum. Changes in body positions immediately following the increases in moments of inertia caused a shortening of the

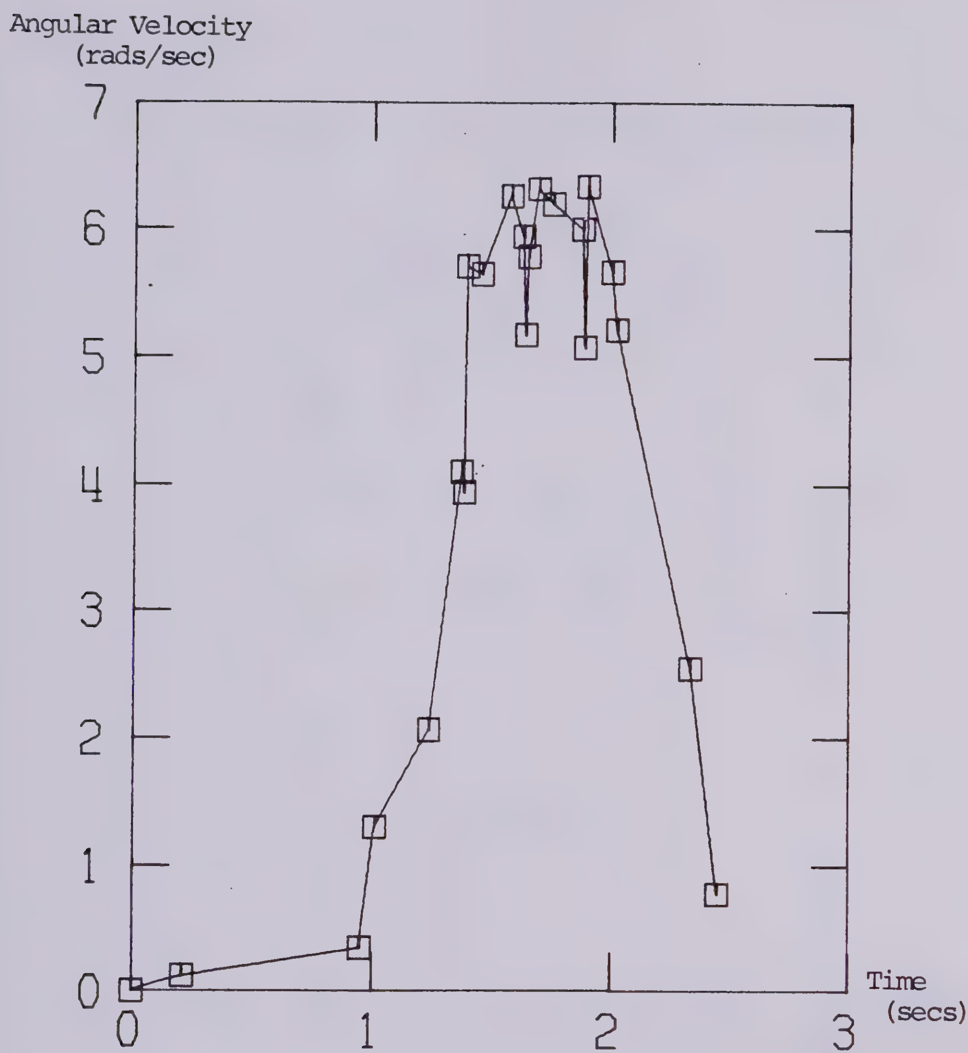

Figure 15. Angular Velocity (Wr) for Subject JM

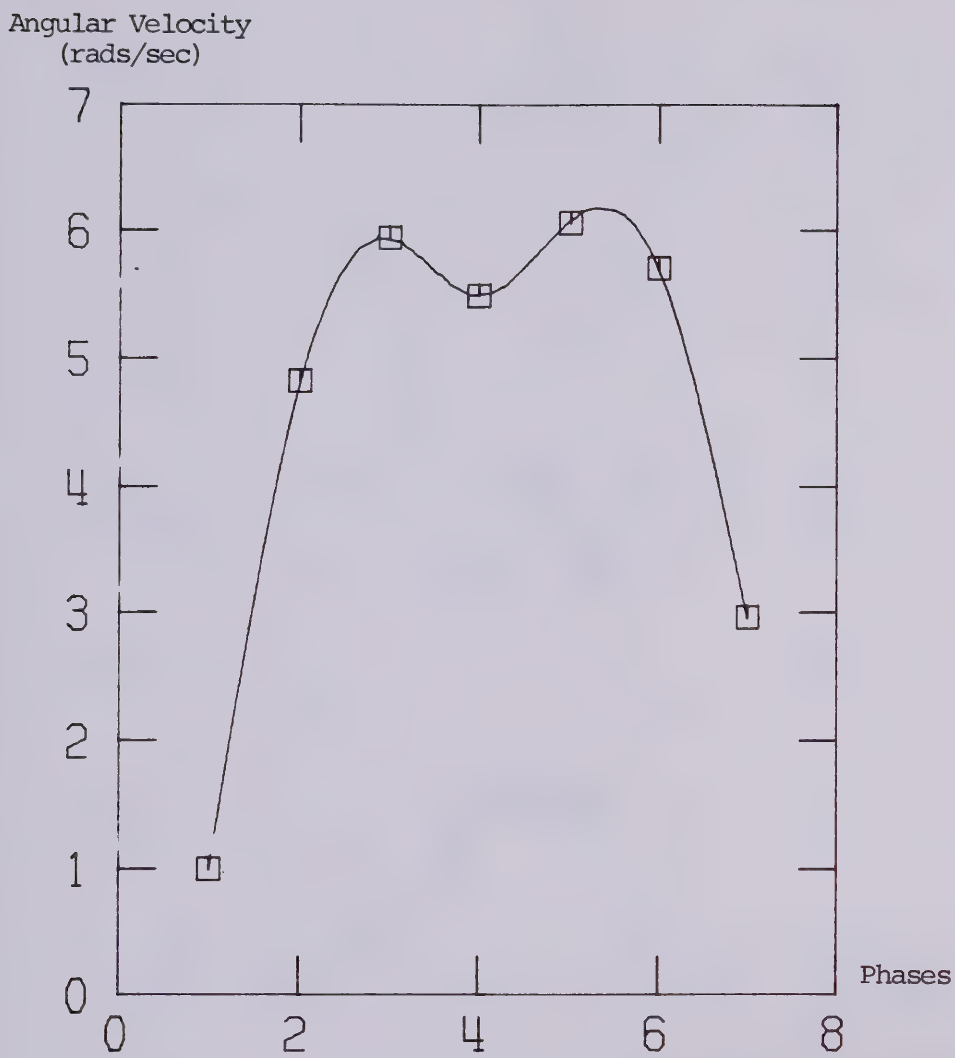

Figure 16. Smoothed Angular Velocity (Wr) Curve for Phases of Execution for Subject JM.

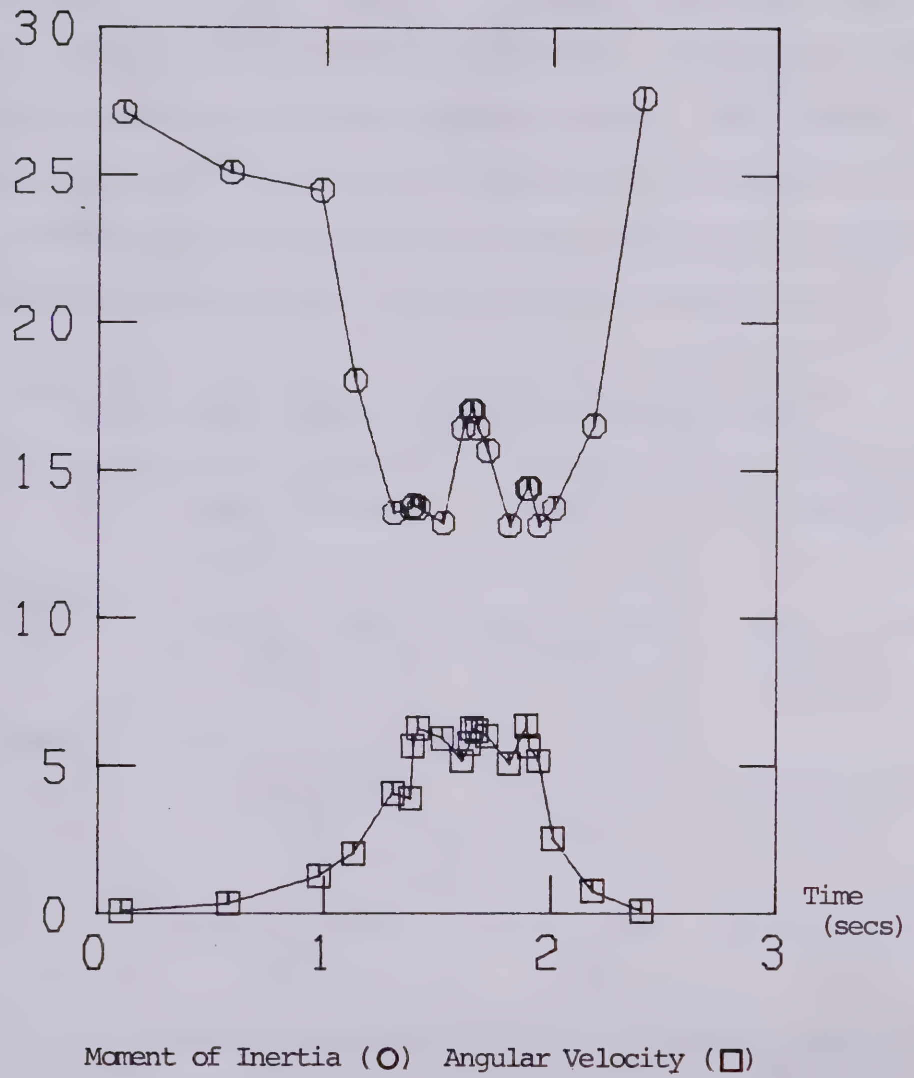

Figure 17. Relationship Between Angular Velocity (Wr) and Moments of Inertia (Ir) for Subject JM.

radius of rotation, thus decreasing the moment of inertia with a consequential increase in angular velocity. This second increase in angular velocity occurred as JM passed the high bar on the up swing. Gradual decrease in the angular velocity occurred throughout the straddle-out phase as gravity acted against the gymnast and as the moment of inertia increased to slow rotation as JM extended to the final handstand position. Between the final two frames JM had an angular velocity of .8rads/sec (45 degrees/sec).

Table 10. Angular Velocity Data For Total Swing, Down Swing and Up Swing in Radians/Second

	ALL TRIALS	GROUP I	GROUP IV
TOTAL SKILL			
RANGE	1.92 - 2.91	2.43 - 2.91	1.92 - 2.68
MEAN	2.51	2.64	2.39
S.D.	.60	.02	.08
DOWN SWING			
RANGE	1.51 - 2.54	1.73 - 2.54	1.64 - 2.23
MEAN	2.01	2.16	1.95
S.D.	.07	.08	.06
UP SWING			
RANGE	2.19 - 3.90	3.01 - 3.89	2.19 - 3.55
MEAN	3.18	3.33	2.93
S.D.	.16	.12	.15

The angular momentum generated throughout the down swing had to be sufficient to insure ample angular momentum in the up swing while gravity acted in the opposite line of direction to the desired movement. Changes in angular momentum throughout the Stalder for JM are illustrated in

Figure 18. Due to the force of gravity pulling the gymnast downward, the angular momentum increased along with the angular velocity in the down swing even though the moment of inertia was decreasing at this time. The maximum measure of angular momentum reached 123.95Kg.m2/s as JM passed below the high bar on the bottom swing. Drops in angular momentum immediately preceding and following this measure corresponded to the drops in angular velocity occurring at the beginning of the bottom swing and the onset of the straddle-out action (Fig. 19).

The force generated downward against the rail as JM passed below the bar and as measures of angular momentum were at their maximum was calculated to be 751.15N. This measure is equivalent to 1.99 times JM's body weight (Kg). Attempting to control forces nearly twice that normally acting on the body could have produced an eccentric contraction in the shoulder extensor muscles causing the increased shoulder flexion measured through Phase 4 which affected the moment of inertia, angular velocity and, therefore, the angular momentum.

As JM rotated about the rail changes in body position caused changes in the angular velocity of her own body about its center of mass. These changes are illustrated in Figure 20. Angular velocity about the center of mass was low throughout the straddle-in action (Wcm: Phase 1=5.71 rads/sec) due to the slow straddling in of the legs and the

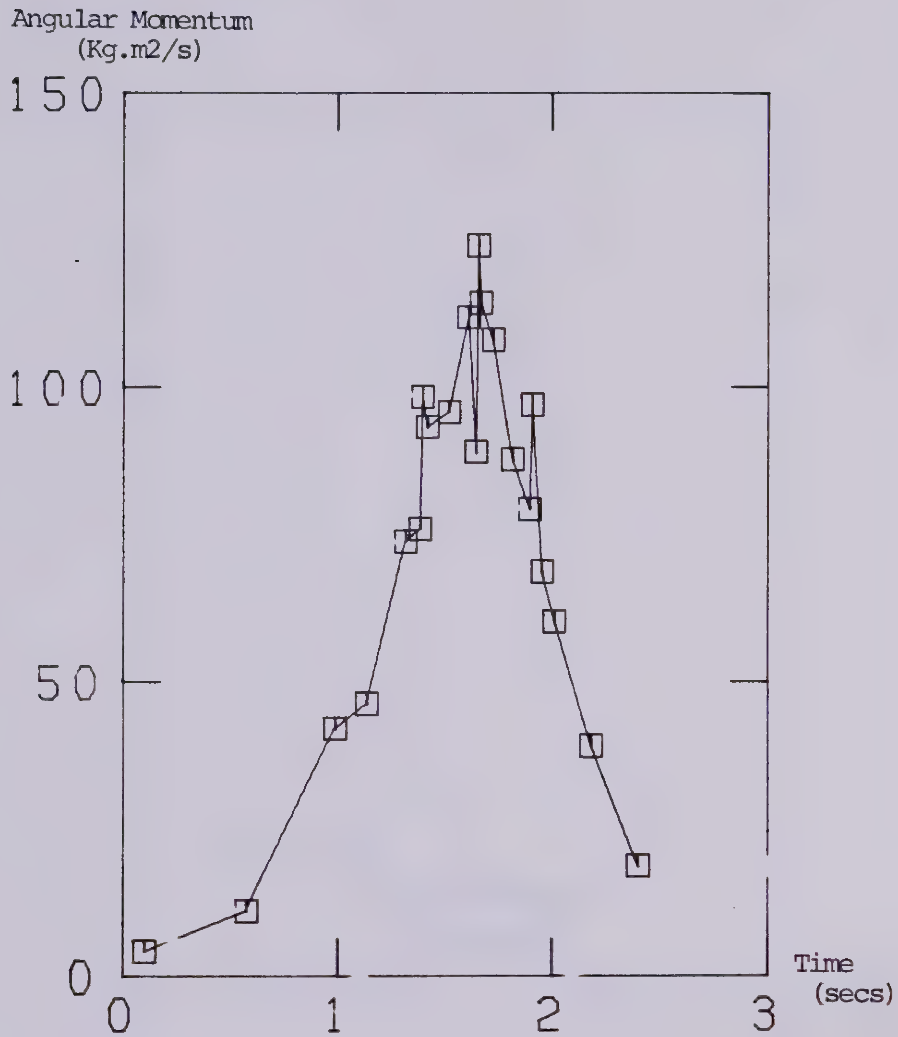

Figure 18. Angular Momentum (Hr) for Subject JM.

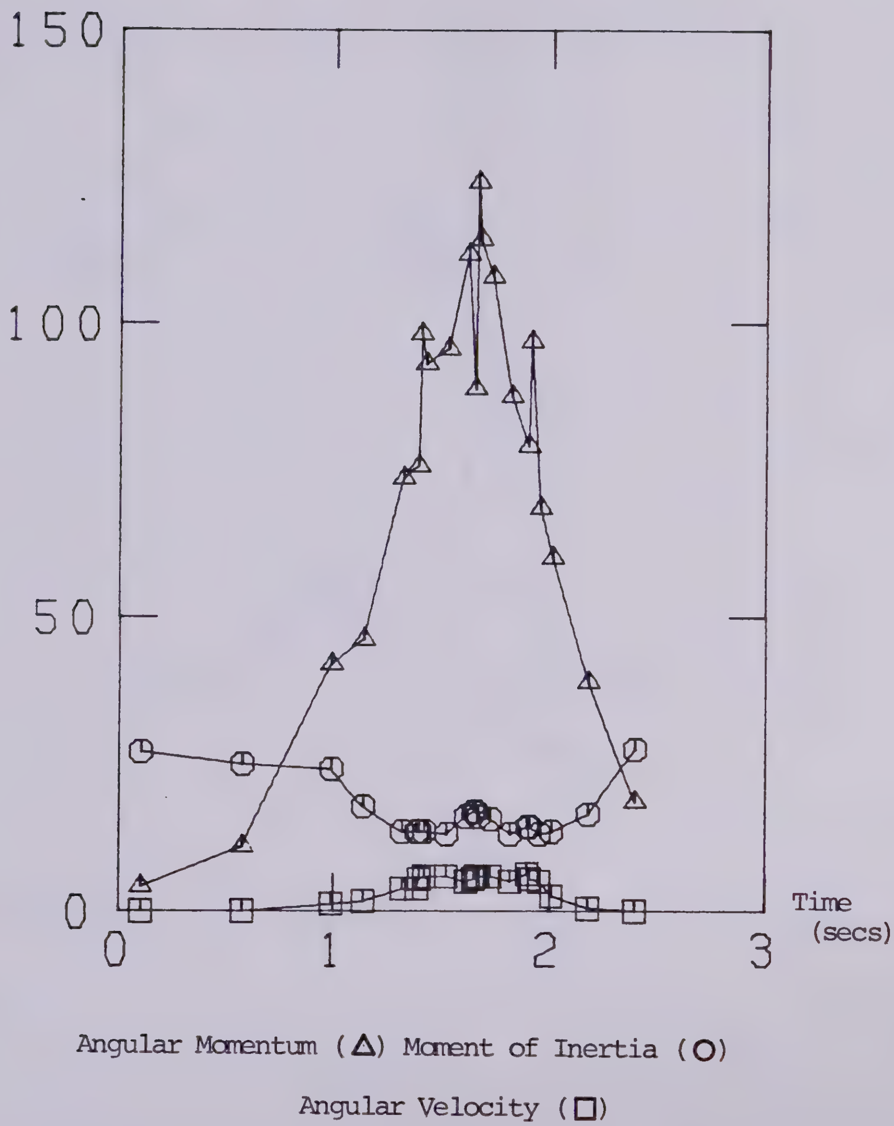

Figure 19. Relationships Among Angular Momentum (Hr), Moments of Inertia (Ir), and Angular Velocity (Wr) for Subject JM.

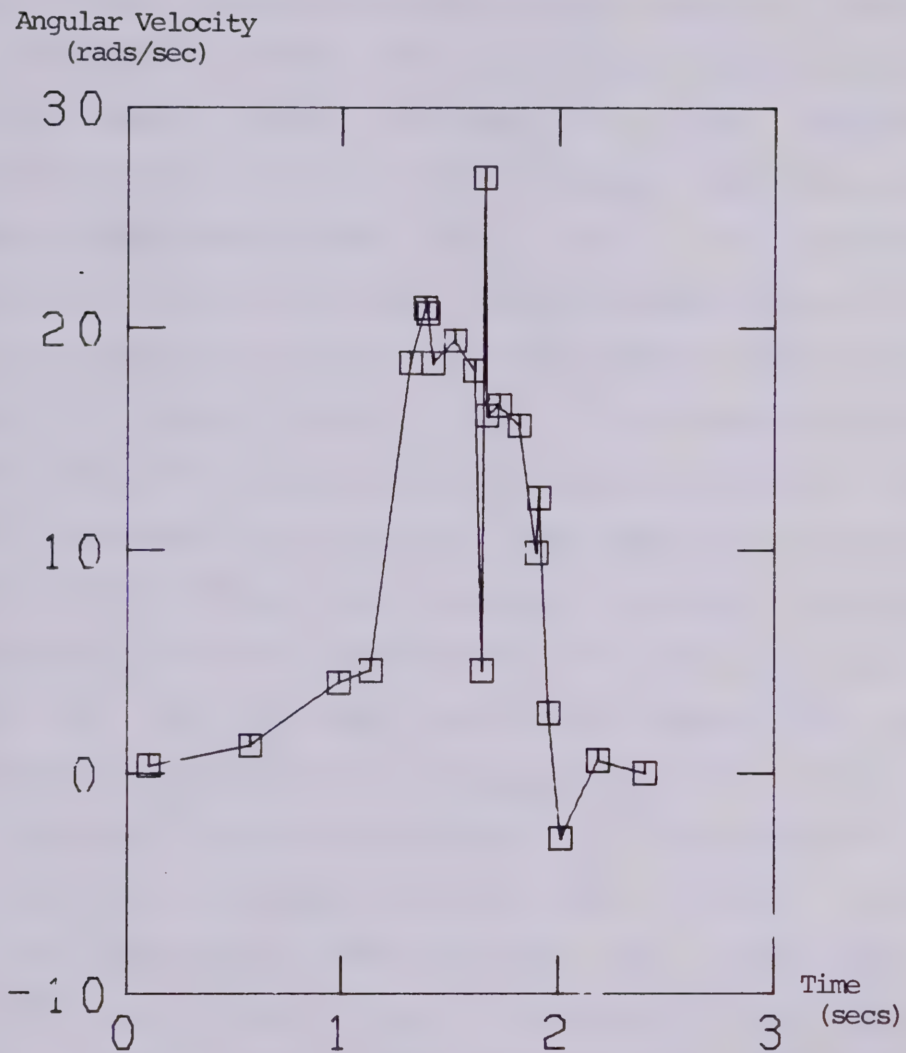

Figure 20. Angular Velocity (Wcm) for Subject JM.

small amount of shoulder extension performed in this phase. The rock back action caused by more rapid shoulder extension and hip flexion showed an increase in the angular velocity about the center of mass. There was a large drop in angular velocity (Wcm) (18.15 rads/sec to 4.62 rads/sec) accompanying the increase in shoulder angle that occurred as JM passed below the high bar (Fig. li-p). The eccentric contraction caused by gravity and the downward force of the gymnast's body at this point acted and placed the extensor muscles on forced stretch. As a stretched muscle can contract more forcefully, shoulder extension could be more easily performed at this point even though the action was against the pull of gravity. Shoulder extension performed to reduce the radius of rotation thus decrease the moment of inertia (Ir) and increase the angular velocity (Wr) also caused the greatest measure of angular velocity (Wcm) at 26.75 rads/sec noted in the Stalder. As JM extended to the final position, the angular velocity (Wcm) dropped rapidly to a low measure of -2.94 rads/sec. The angular momentum about the center of mass (Fig. 21) followed a very similar pattern to that of the angular velocity (Wcm). Because the moment of inertia (Icm) varied very little throughout the skill, changes in the angular velocity (Wcm) were responsible for the changes in the angular momentum (Hcm).

The amount of angular momentum (Hcm) at the beginning (1.44 Kg.m2/s) and the end (.09 Kg.m2/s) of the skill were quite small. This indicates that changes in body position

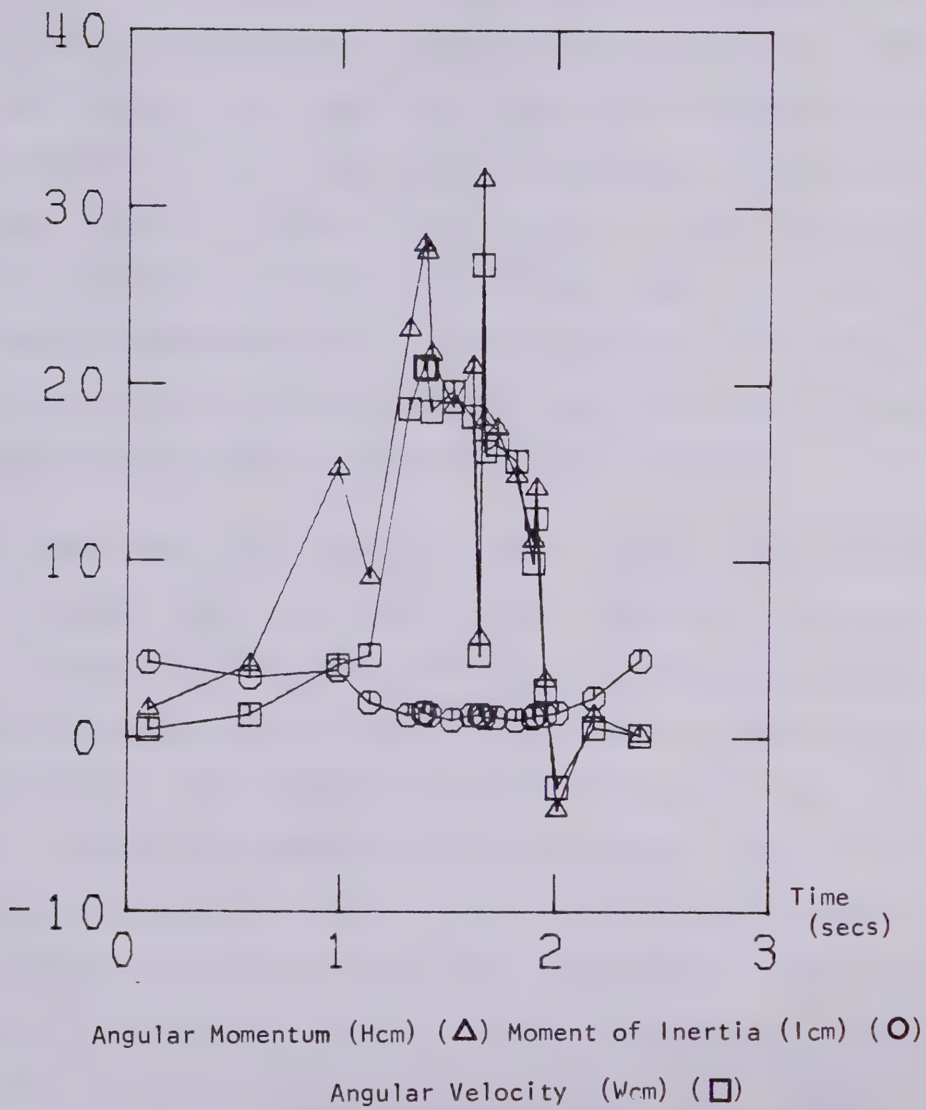

Figure 21. Relationships Among Angular Momentum (Hcm), Moments of Inertia (Icm), and Angular Velocity (Wcm) for Subject JM.

were at a minimum. Similar patterns in the angular momentum (Hr) and the angular momentum (Hcm) existed indicating that changes about the center of mass and the rail for both moments of inertia and angular velocity were similar (Fig. 22). Although there was very little rotation of the body about the center of mass at the end of the skill, the angular momentum (Hr) measured 18.64Kg.m2/s between the final two frames. This shows that JM had generated sufficient angular momentum in the down swing to have a large angular momentum (Hr) at the completion of the skill, thus allowing the continued rotation about the rail after the gymnast had attained an extended body position.

AD performed the Stalder with greater measures of angular velocity about the rail for the total skill and all phases (except the straddle-in action of Phase 1) than JM. AD had an average angular velocity (Wr) of 2.65 rads/sec for the total skill, 2.23 rads/sec for the down swing and 3.03 rads/sec of angular velocity for the up swing. The pattern of angular velocity (Wr) showed a period of negative angular velocity during the beginning of the straddle-in action as AD rotated through the reverse line of direction of Stalder action (Fig. 23). Positive angular velocity (Wr) began at .54 seconds into the skill and increased to 7.06 rads/sec just prior to the bottom swing. The drop in angular velocity (Wr) noted in JM's performance as she passed below the rail was duplicated in AD's performance. Figure 24 is a smoothed data curve for the mean values of angular velocity

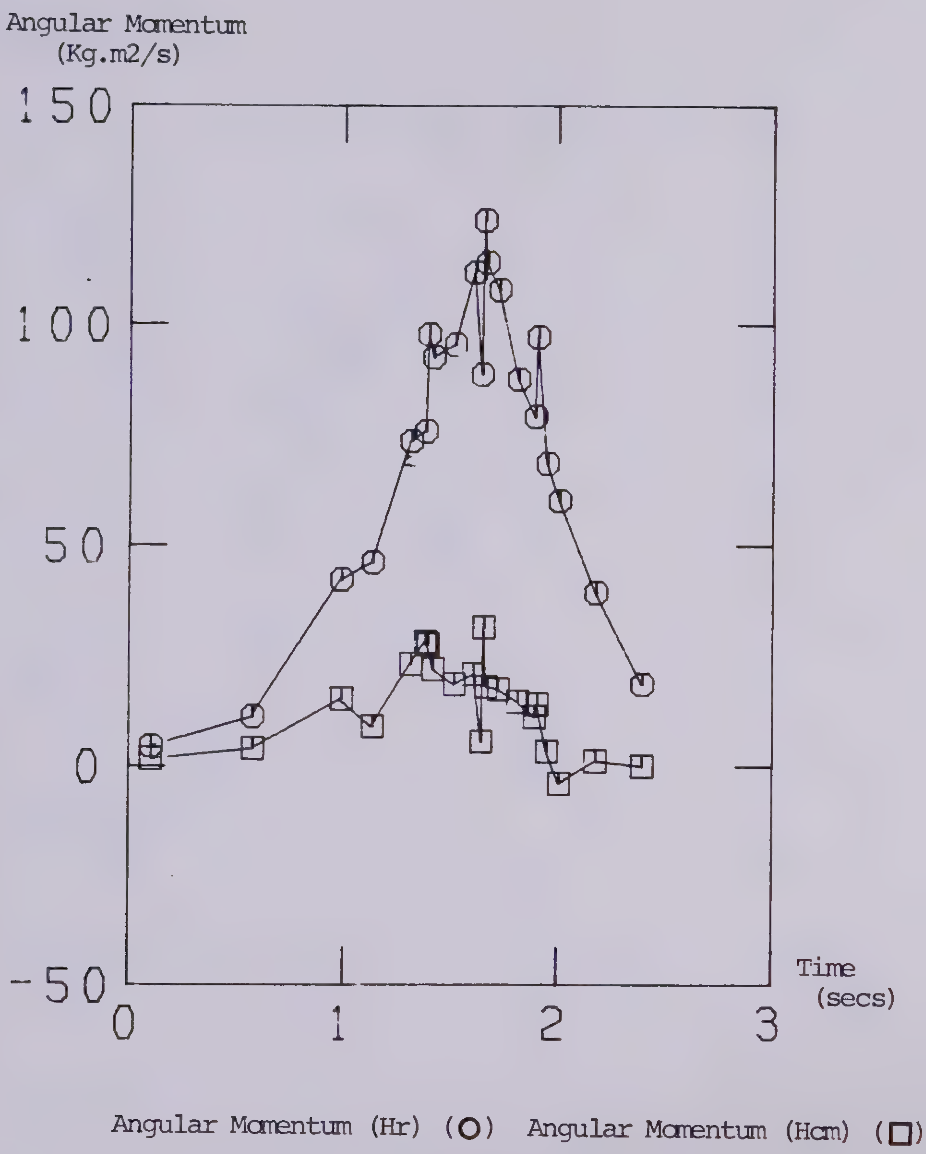

Figure 22. Relationship Between Angular Momentum (Hr) and Angular Momentum (Hcm) for Subject JM.

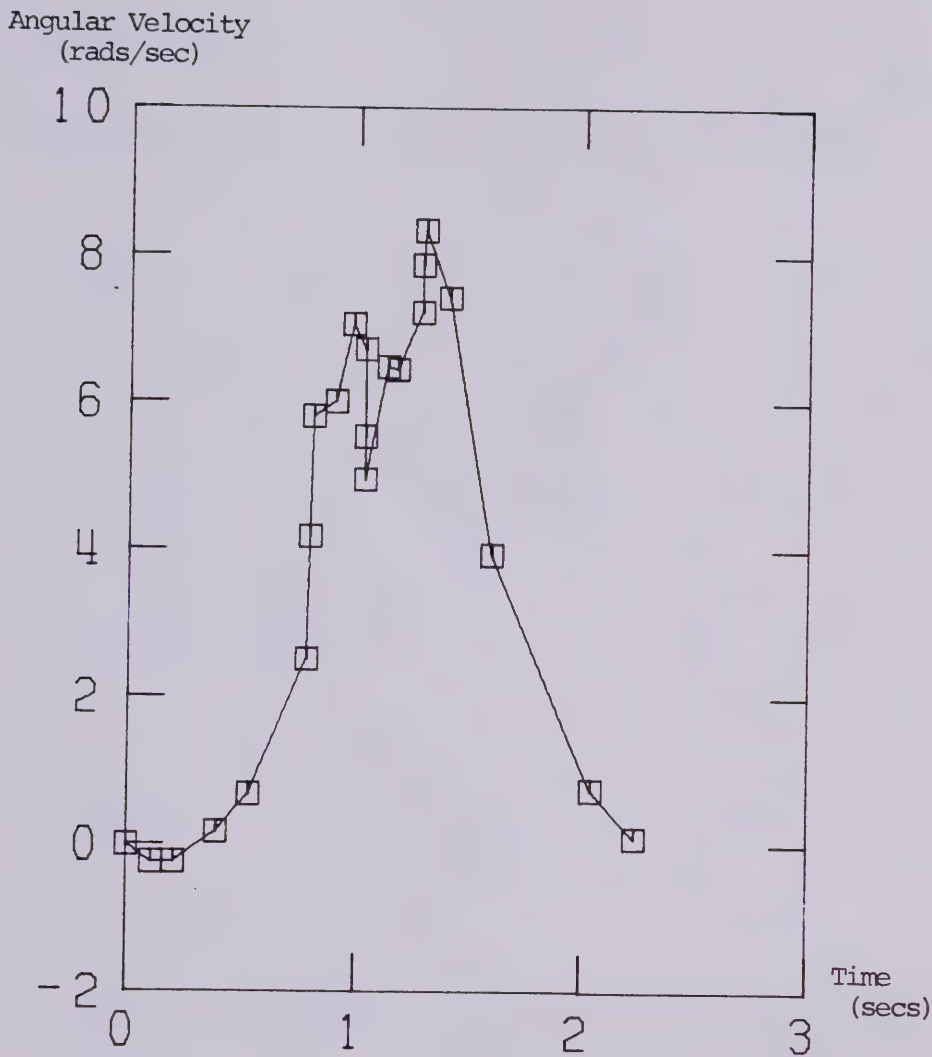

Figure 23. Angular Velocity (Wr) for Subject AD.

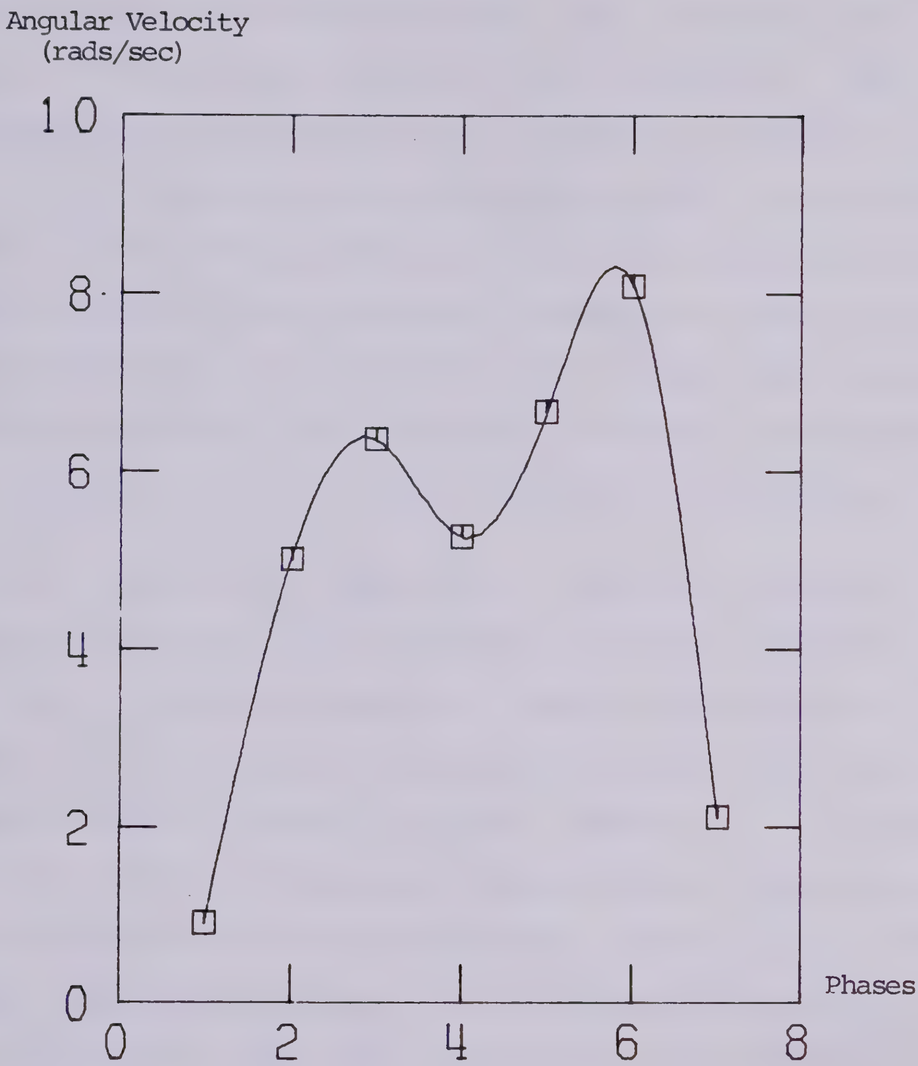

Figure 24. Smoothed Angular Velocity (Wr) Curve for Phases of Execution for Subject AD.

(Wr) for the seven phases of the Stalder. AD showed a single point of decreased angular velocity (Wr) at frame 12. Angular velocity (Wr) dropped from 7.06 rads/sec to 4.96 rads/sec as she passed below the rail in Phase 4. This was accompanied by an increase in the moment of inertia (Ir) (Fig. 25). Throughout the bottom swing and the first part of the up swing AD's angular velocity (Wr) increased to 8.32 rads/sec before dropping steadily through the final phase of the straddle-out. As AD completed the straddle-out action, her angular velocity (Wr) measured .1 rads/sec. indicating a rapid decrease in angular velocity during the up swing.

The pattern of changes in angular momentum (Hr) followed closely the changes noted the angular velocity (Wr) (Fig. 26). A negative measure of angular momentum (Hr) was produced due the negative angular velocity at the beginning of the straddle-in action. Angular momentum (Hr) increased from the point of positive displacement of the center of mass through the down swing except for a drop in the middle of the straddle-in action. AD performed the action with a rapid extension of the upper extremity at the shoulders and a rapid flexion of the lower extremity to the trunk at the hips at the beginning of the straddle-in. These body position changes caused a change in the center of mass within the body which produced a slight decrease in the moment of inertia (Ir) and a larger drop in angular velocity (Wr) to produce a drop in the angular momentum (Hr) at that point (Figure 27). Angular momentum (Hr) increased to a

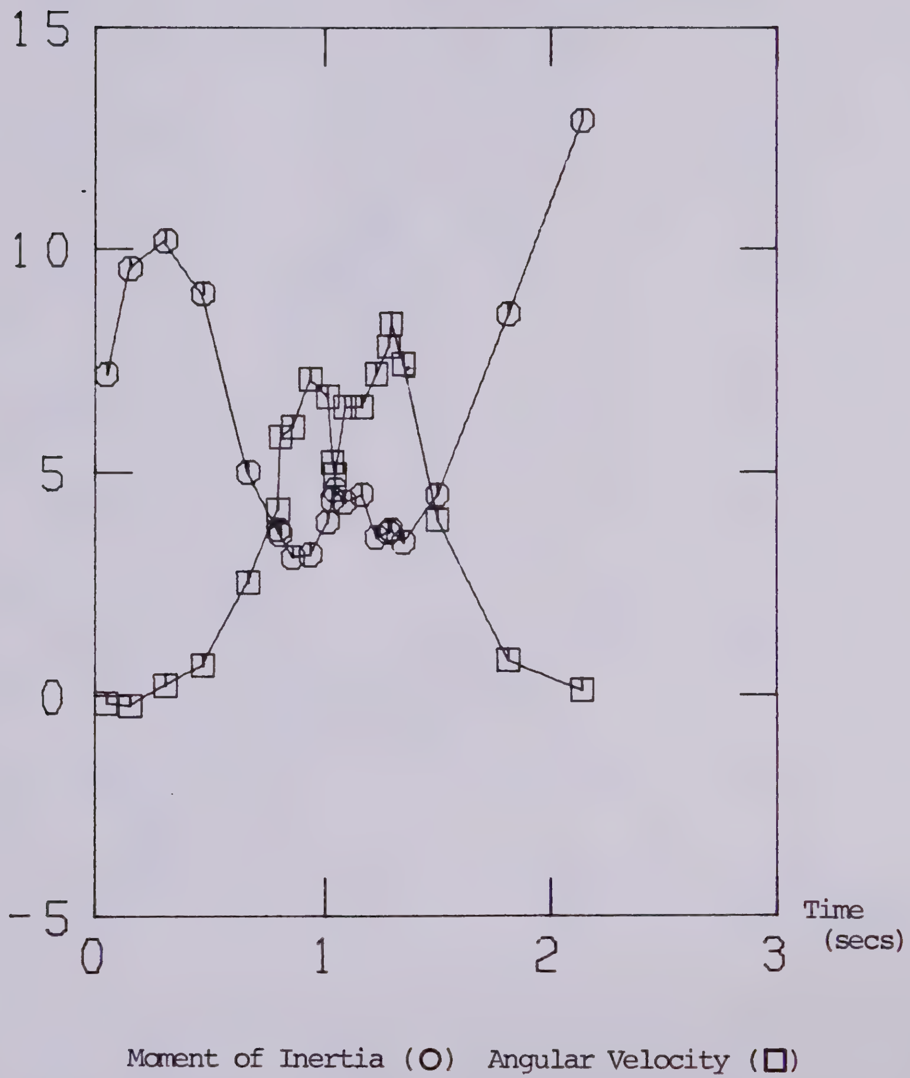

Figure 25. Relationship Between Moments of Inertia (Ir) and Angular Velocity (Wr) for Subject AD.

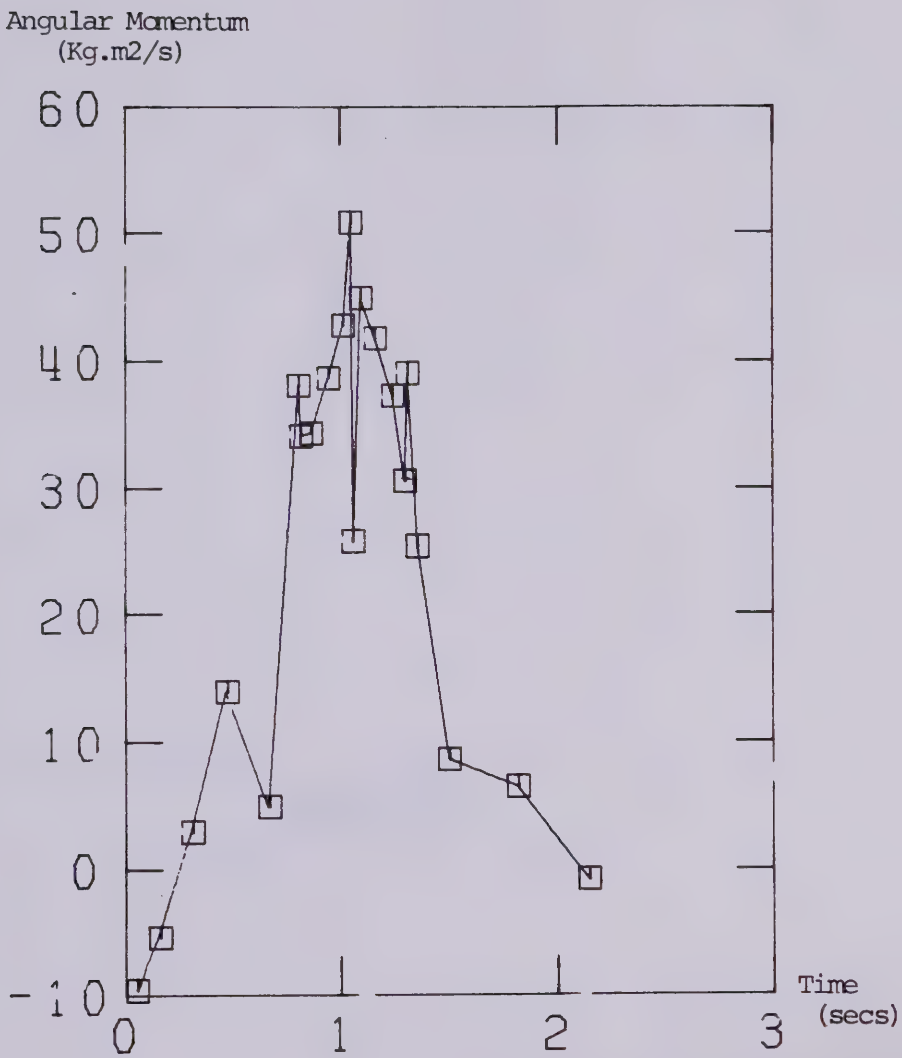

Figure 26. Angular Momentum (Hr) for Subject AD.

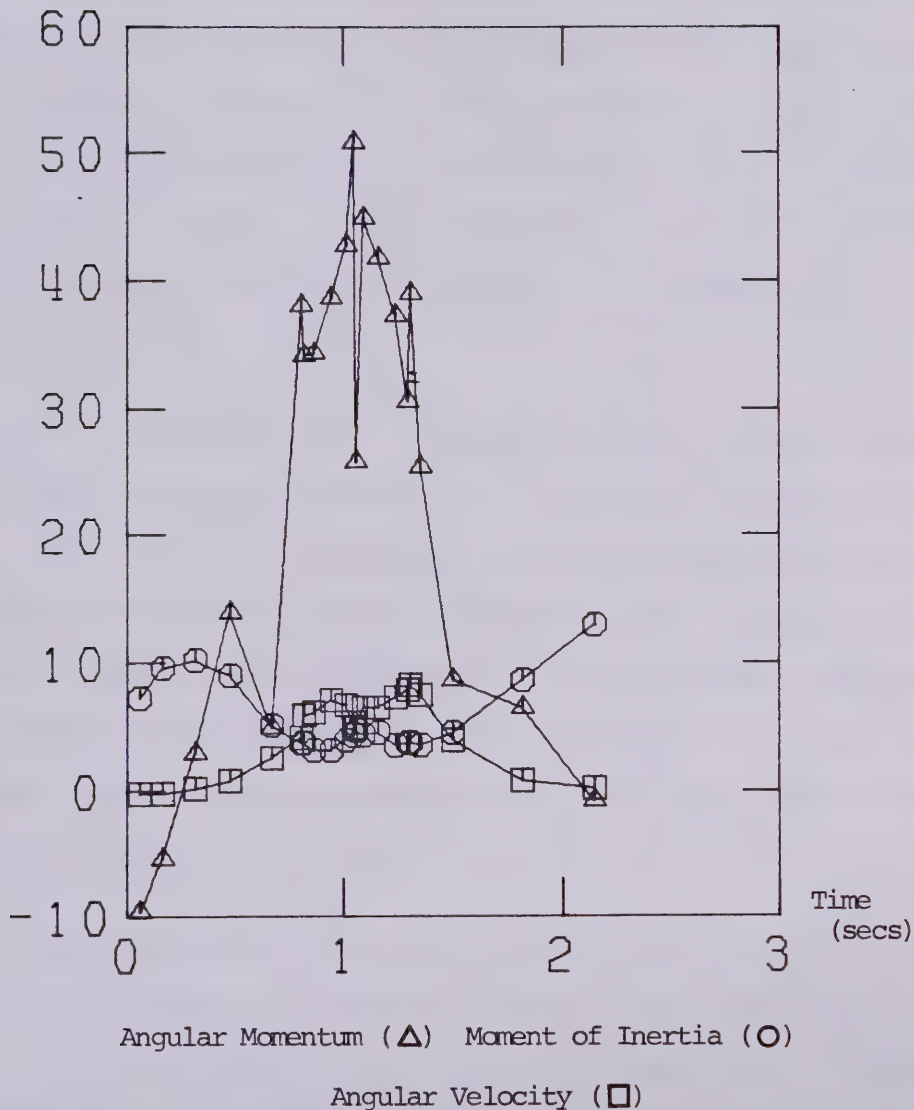

Figure 27. Relationships Among Angular Momentum (Hr), Moments of Inertia (Ir), and Angular Velocity (Wr) for Subject AD.

maximum of 50.83 Kg.m2/s just prior to the bottom swing. A large drop in angular momentum (Hr) from 50.83 Kg.m2/s to 25.71 Kg.m2/s occurred as AD began the bottom swing. An increase in the moment of inertia (Ir) caused this drop in angular momentum (Hr). In the performance by AD, the change in the moment of inertia (Ir) was caused by a continuation of shoulder extension which caused the body to further rotate about itself. This caused the legs to drop which dropped the center of mass and caused an increase in the radius of rotation.

Angular momentum (Hr) dropped off at a rate so great that AD had a negative measure of angular momentum (Hr) between the final two analyzed positions (Hr=-.06Kg.m2/s). This indicates that the angular momentum (Hr) generated in the down swing was insufficient to overcome the downward pull of gravity in the up swing and caused AD to begin to fall back down the up swing side of the rail at the completion of the skill.

The force generated downward against the rail as AD passed below it was at a maximum for the skill and measured 281.86N. This was equivalent to 1.07 times AD's weight (Kg). The angular momentum (Hr) generated in the down swing was, therefore, great enough only to produce a force slightly greater than AD could produce by simply hanging from the rail. Although this small amount of force could be controlled more easily by the gymnast, it indicated that

sufficient angular momentum to overcome the downward pull of gravity throughout the entire up swing was most likely not present. This result is concluded from the fact the AD had a negative measure of angular momentum (Hr) at the conclusion of the skill.

Measures of angular velocity (Wcm) for AD were quite varied throughout the skill. Six decreases in angular velocity (Wcm) occurred indicating that body positions changed frequently throughout the skill (Fig. 28). The greater measures of shoulder extension recorded for AD caused greater rotation of the body about its own center of mass. These greater displacements contributed to higher measures of angular velocity (Wcm). At two points in the Stalder: (1) near the completion of the straddle-in action (-23.26 rads/sec) and (2) near the completion of the straddle-out action (-12.04 rads/sec), changes in the displacement of the body parts about the center of mass were negative indicating extreme changes in body position opposite to those desired for Stalder performance and producing negative values of angular velocity (Wcm) (Fig. 2i-p). The angular velocity (Wcm) was negative for the majority of the straddle-out action. This was caused due to the extreme hyperextension of the legs and back and flexion then extension of the upper extremity at the elbows. This work was performed by AD to compensate for the lack of angular momentum (Hr) and to aid in achieving the final position.

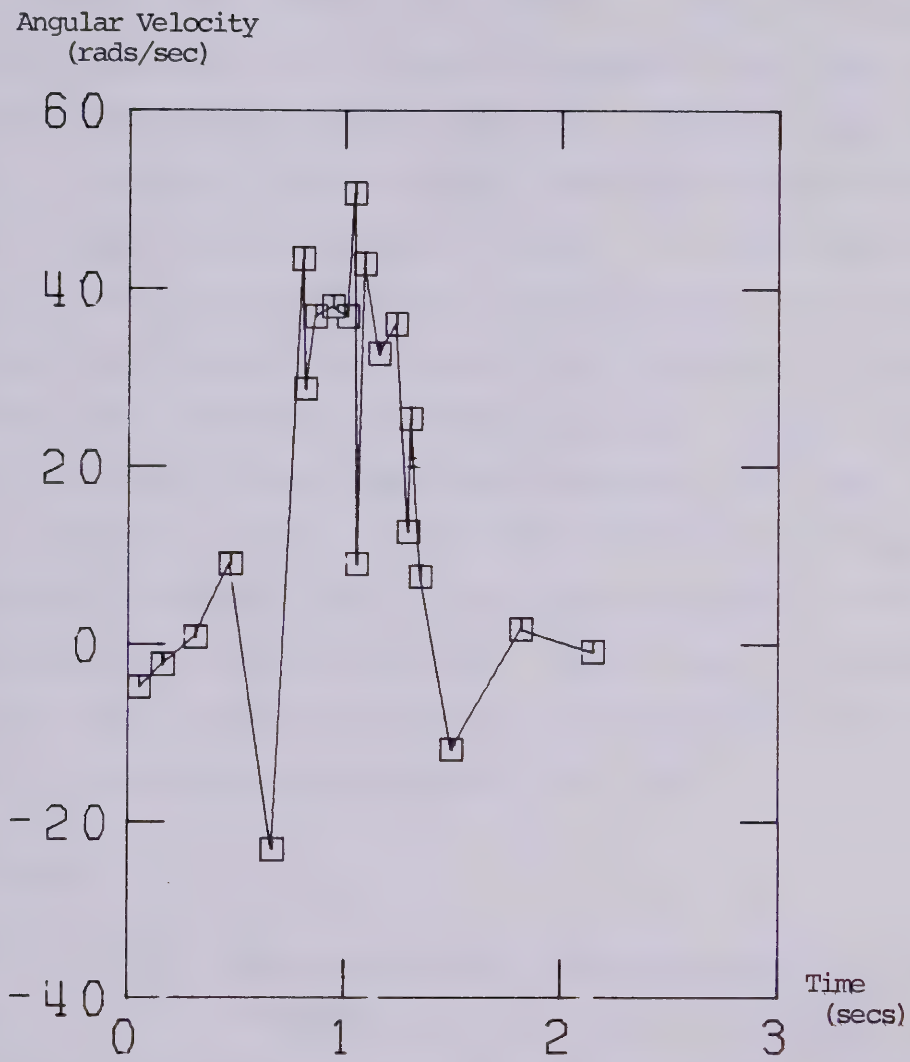

Figure 28. Angular Velocity (Wcm) for Subject AD.

Changes in the angular momentum (Hcm) followed closely the changes occurring in the angular velocity (Wcm) (Fig. 29). Because the moment of inertia (Icm) varied only slightly, this effect on the angular momentum (Hcm) was only during the straddle-in and straddle-out actions when the moment of inertia (Icm) changes were their greatest The changes in the angular momentum (Hcm) at the beginning (-9.08 Kg.m2/s) and at the end (-2.06 Kg.m2/s) of the skill were large and negative indicating that changes in body position were extensive at these points. Due to the negative measures of both the angular momentum (Hr) and the angular momentum (Hcm) at the end of the skill AD had to perform work to adjust the body position to attain the final extended position above the rail as there was no angular momentum (Hr) in the direction of the Stalder to carry the gymnast to a position above the rail (Fig. 30).

Energy

The extended handstand position attained by JM at the beginning of the Stalder put her into a position to potentially produce the greatest amount of angular momentum possible in the down swing. This position, as well, produced a large measure of gravitational potential energy which would allow the generation of large amounts of kinetic energy (T) which could be utilized in the up swing.

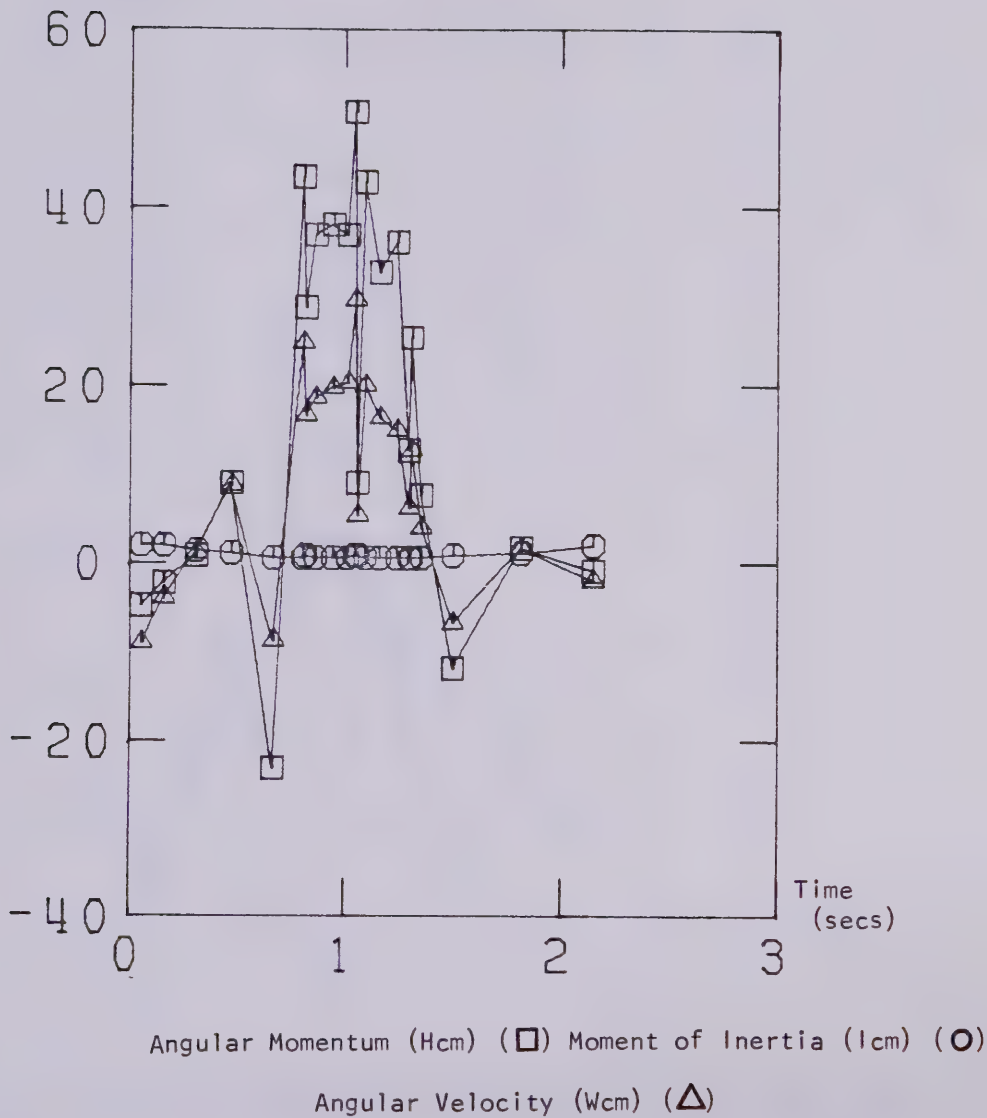

Figure 29. Relationships Among Angular Momentum (Hcm), Moments of Inertia (Icm), and Angular Velocity (Wcm) for Subject AD.

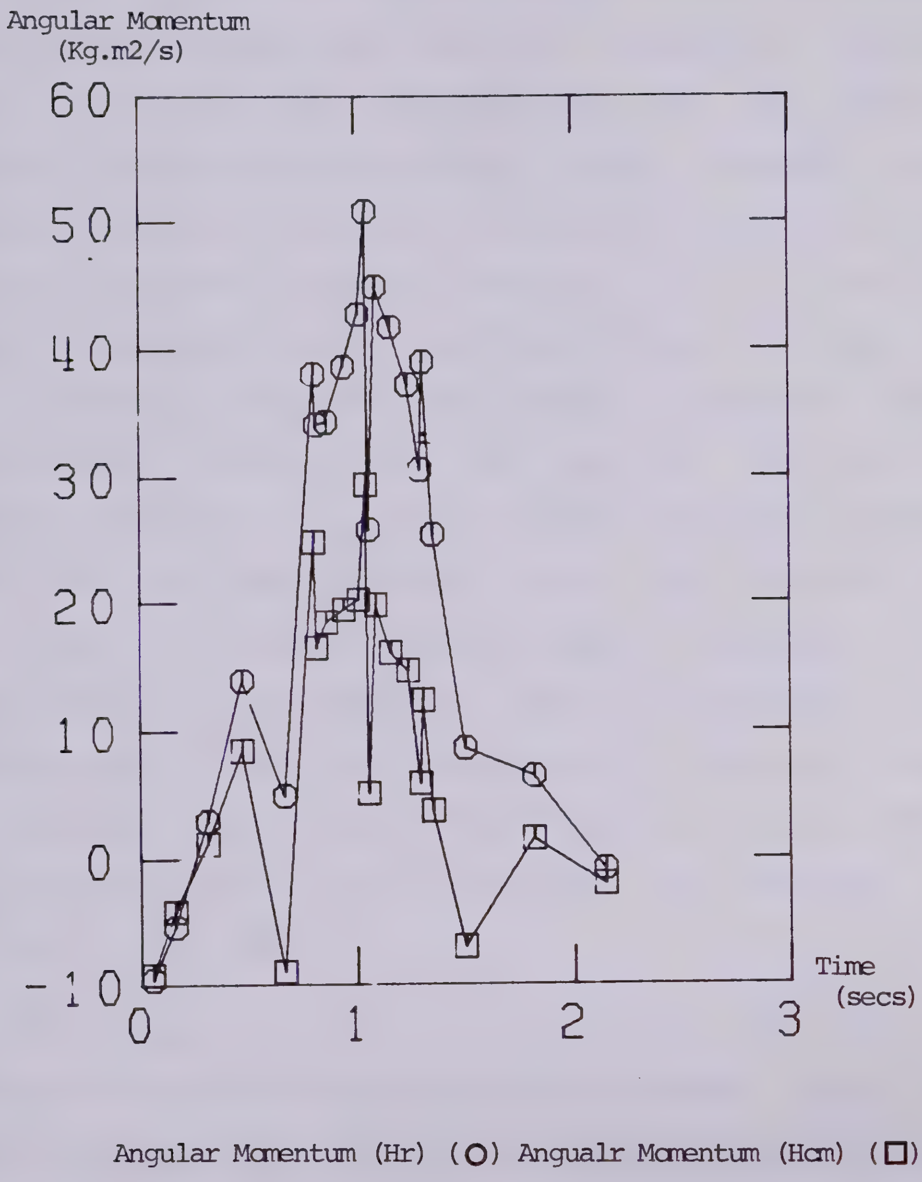

Figure 30. Relationship Between Angular Momentum (Hr) and Angular Momentum (Hcm) for Subject AD.

The location of the center of mass of the body at its lowest point in rotation about the rail was chosen as the datum line or zero point for measures of potential energy. At the initial highest cast position a measure of potential energy of 543.22J was obtained for JM. As would be expected, the measures of potential energy dropped rapidly through the down swing to a point of 0.00J of potential energy as JM passed directly below the rail. The mean measure of potential energy for Phase 4 was 4.70J (Fig. 31). This indicated that only small changes in potential energy occurred as JM passed below the rail at the point of greatest downward acceleration, angular momentum and force against the rail. The inverted dorsal hang position was maintained at a fairly constant level. Throughout the up swing, the measures of potential energy increased to the final position of 536.17J. The measures of potential energy at the start and the end of the Stalder were quite similar indicating maximum utilization of energy and muscular work performed in the skill.

The changes in total kinetic energy (T) (Fig. 32) increased through the down swing and decreased through the up swing in opposition to potential energy measures as would be expected (Fig. 33). JM performed a very slow straddle-in action, keeping the body extended and minimizing the increase in angular velocity (Wr), angular velocity (Wcm), angular momentum (Hr) and angular momentum (Hcm) for as long as possible. This action, although performed with an

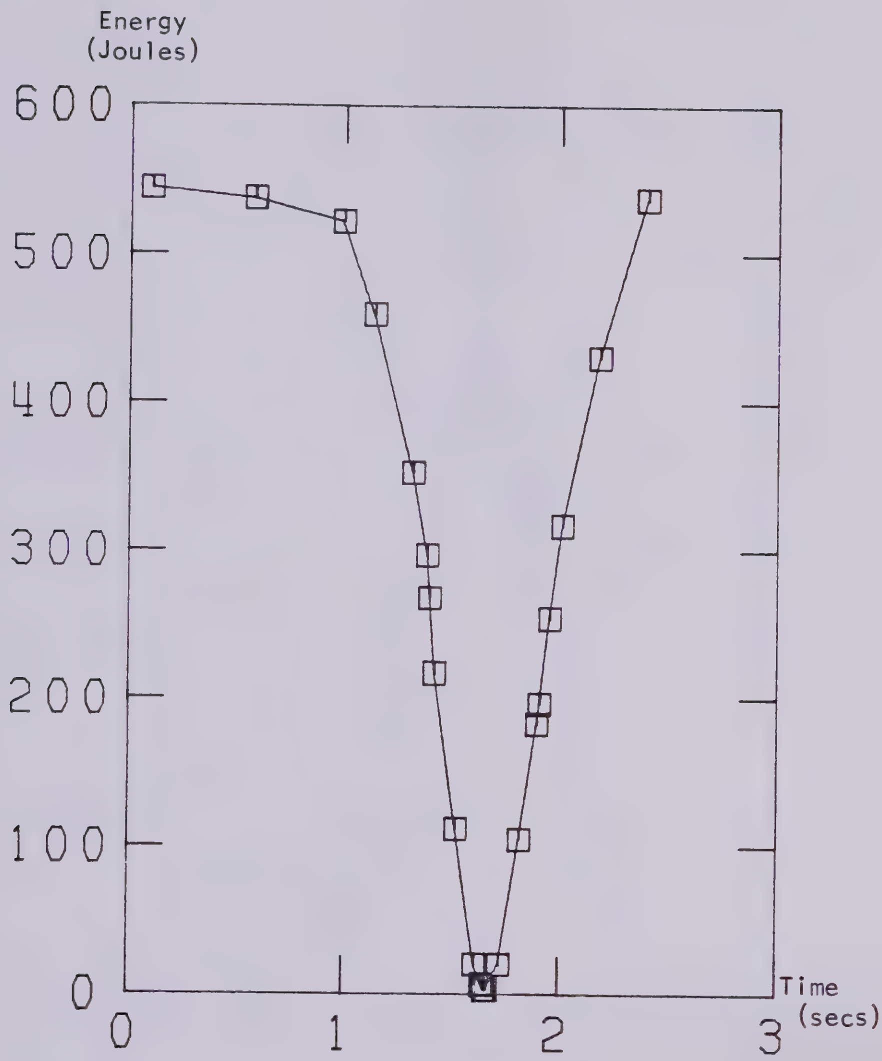

Figure 31. Potential Energy for Subject JM.

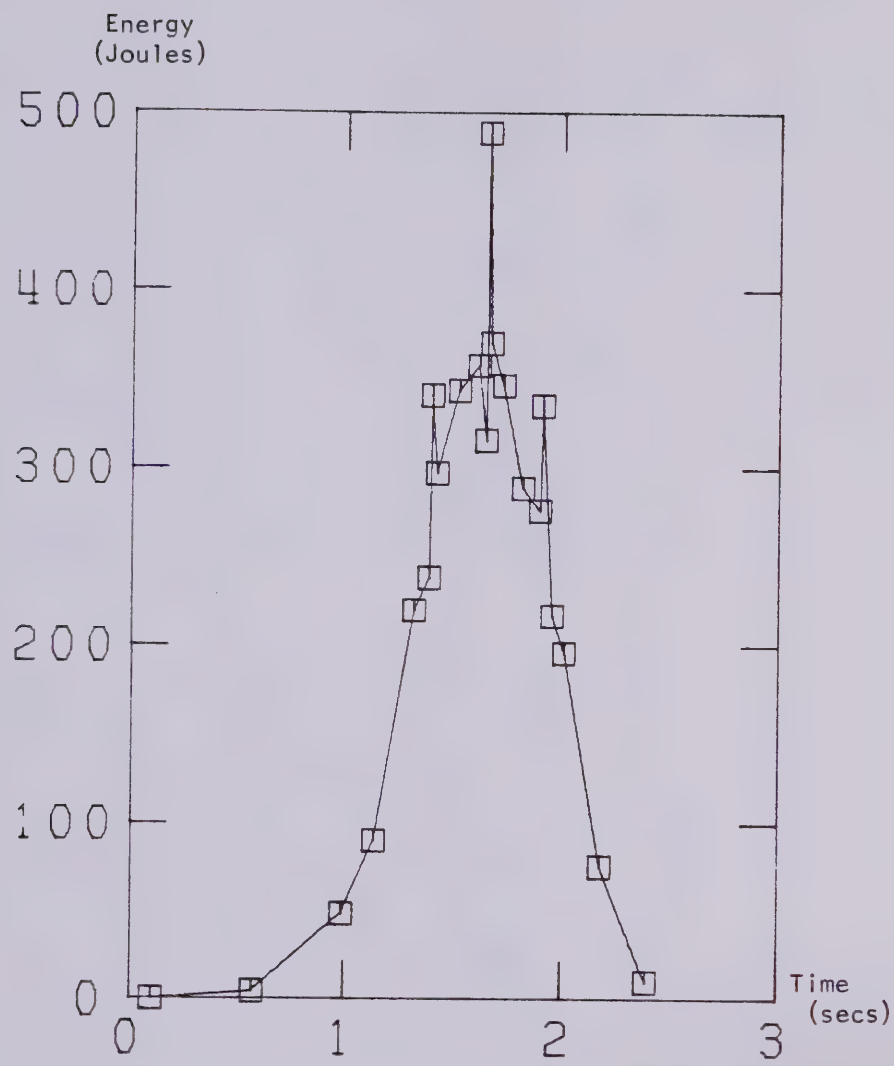

Figure 32. Kinetic Energy (T) for Subject JM.

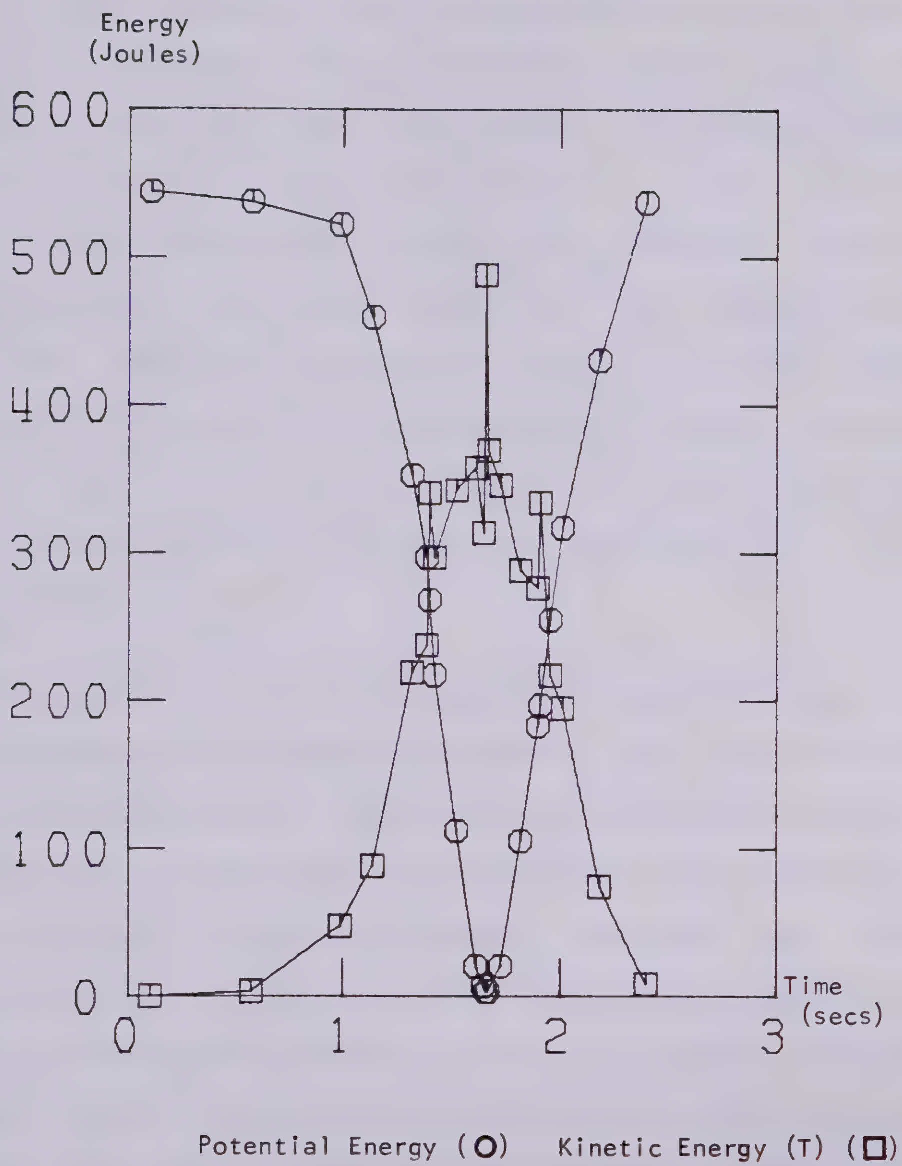

Figure 33. Relationship Between Potential Energy and Kinetic Energy for Subject JM.

optimum moment of inertia, produced little angular velocity (Wr), therefore the measures of kinetic energy (T) were small in the beginning of the straddle-in action (0.4J - 48.20J). As potential energy decreased, kinetic energy (T) increased throughout the down swing to a maximum energy value of 487.70J at exactly the point of zero potential energy. The difference between the maximum values of potential energy and kinetic energy (T) was approximately 55J. The difference between the amount of kinetic energy (T) potentially possible to produce and the amount actually produced can be attributed to air resistance and friction forces between the hands and the rail retarding the action of the gymnast.

The amount of kinetic energy decreased throughout the up swing except for a slight increase at the beginning of the straddle-out action. The increase in kinetic energy (T) from 275.70J to 334.00J corresponded to the increases in angular velocity (Wr) and angular momentum (Hr) which occurred at this point. Muscular work performed by the gymnast to shorten the radius of rotation through shoulder and hip flexion thus decreasing the moment of inertia and increasing the angular velocity (Wr) coupled with the recoil of the rail at this same point produced enough force to cause an increase in the kinetic energy (T) sufficient to allow JM to swing to the final handstand position. Between the final two frames a measure of kinetic energy (T) of 10.0J was obtained. This energy measure indicated that even

though JM had completed the Stalder action, her body possessed enough energy to continue circling the rail (Fig. 1p-v).

The total kinetic energy of JM circling the rail was computed by summing the measures of translational and rotational kinetic energy (Fig. 34). The changes in the total kinetic energy (T) were closely aligned with the changes in the translational kinetic energy. These measures were obtained by summing the horizontal and vertical velocities of the segment centers of mass, times the segment mass, about the rail (Fig. 35). Because JM showed little changes in body position between the straddle-in and straddle-out actions, the measures of rotational kinetic energy were smaller by comparison (Fig. 36). The changes in rotational kinetic energy were greatest in Phase 4 as JM passed below the rail. A sudden decrease in rotational kinetic energy followed by a large increase in rotational kinetic energy to a maximum performance value of 126.00J occurred in the bottoming action. Gravity acting to pull the gymnast downward causing an increase in shoulder flexion would be responsible for the drop in rotational kinetic energy. The rapid shoulder extension performed immediately following caused an increase in angular velocity (Wr) which aided in completing the up swing. This change in rotational kinetic energy corresponds to the increase in angular velocity (Wcm). Small increases in both rotational kinetic energy and translational kinetic energy occurred at the

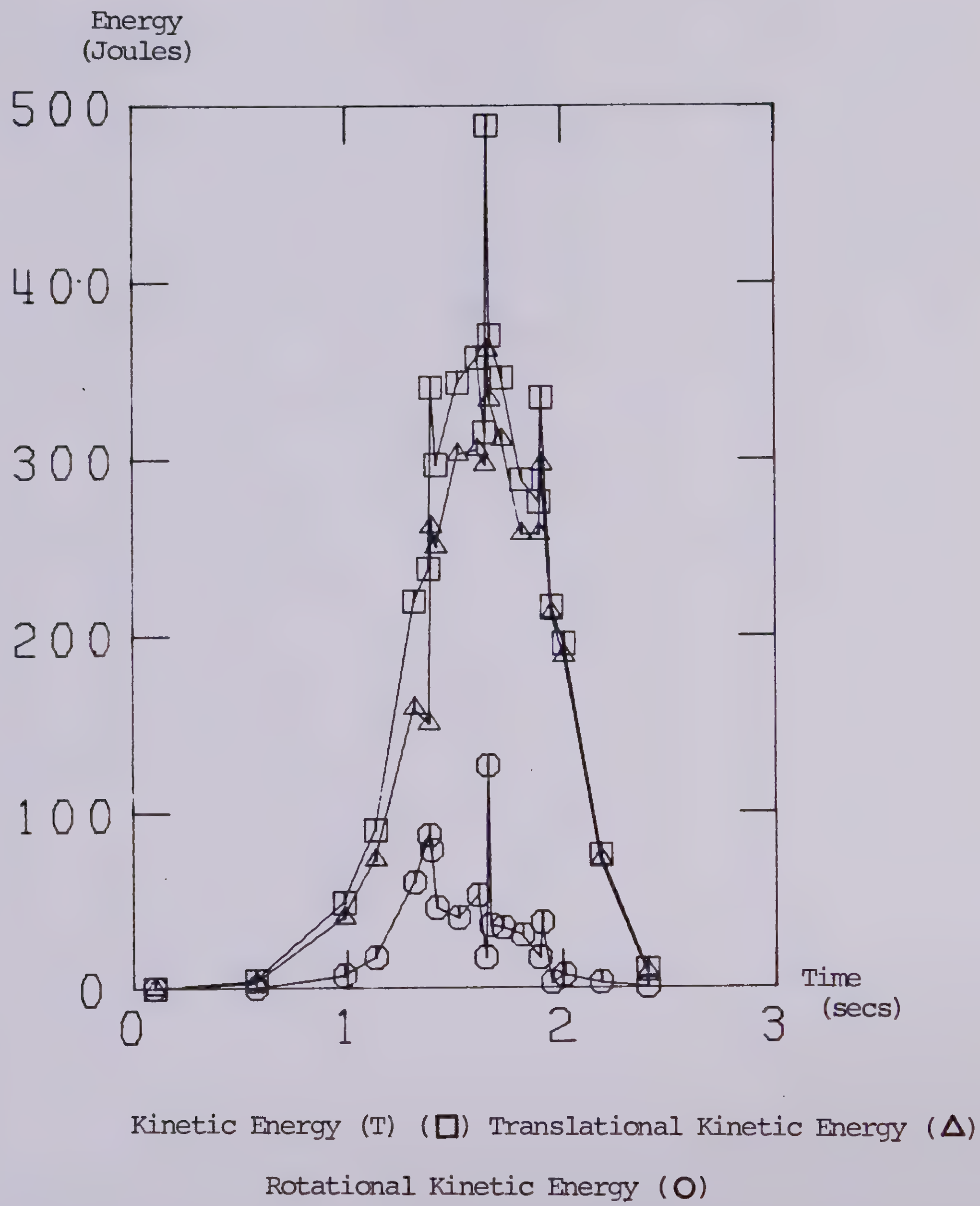

Figure 34. Relationships Among Kinetic Energy (T), Translational Kinetic Energy, and Rotational Kinetic Energy for Subject JM.

Figure 35. Translational Kinetic Energy for Subject JM.

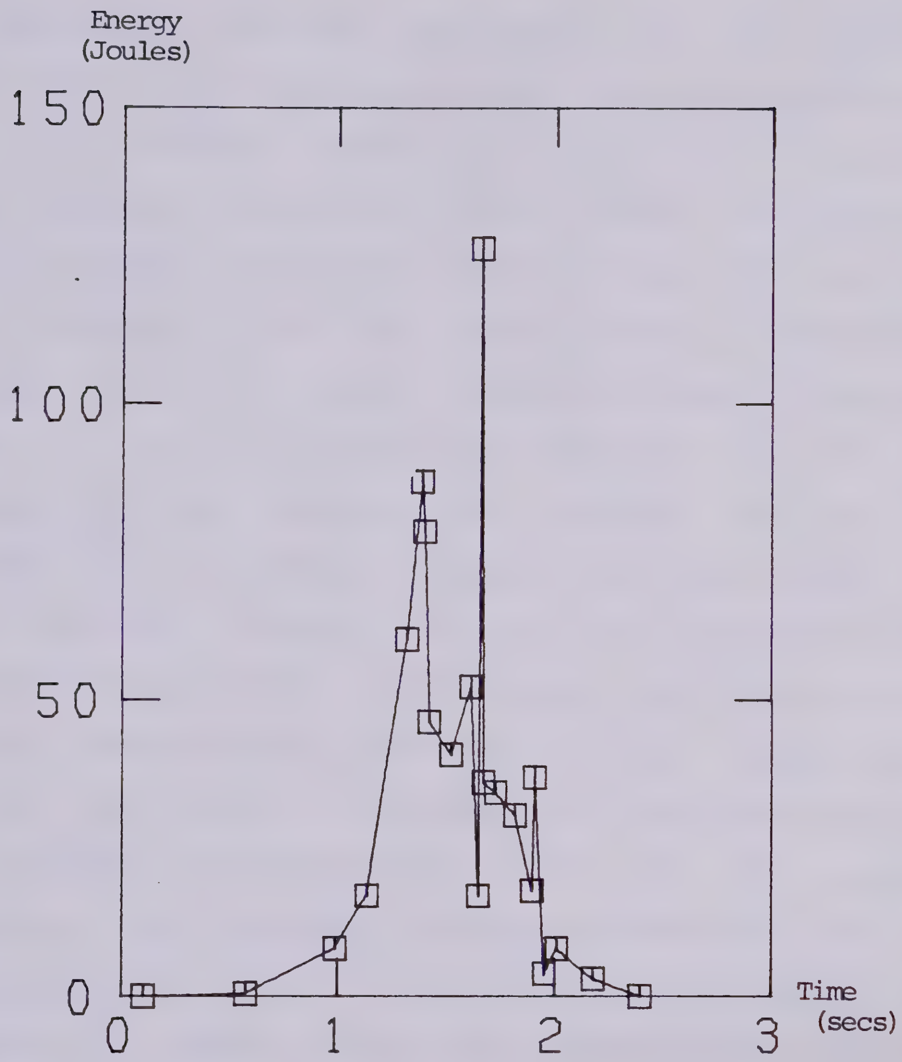

Figure 36. Rotational Kinetic Energy for Subject JM.

beginning of the straddle-out action as occurred in the kinetic energy (T).

Due to the performance technique of AD, the greatest measure of potential energy prior to the down swing did not occur at the initial highest cast position. Potential energy measures rose from 217.91J to 255.87J as AD adjusted her body position to bring her center of mass above the rail in the straddle-in (Fig. 37). Once positive displacement began the potential energy measures dropped to a minimum measure of 0.00J as AD passed below the rail. Due to the continual shoulder extension and rotation of the body performed by AD, the center of mass of her body reached its lowest position in Phase 5 after the hips had passed below the rail but ahead of the center of mass. The mean value of potential energy for AD as her center of mass passed below the rail was 9.48J. Throughout the up swing potential energy increased to a final value of 274.83J. This measure is greater than the initial measure of potential energy as AD completed the Stalder near the handstand position, thus increasing the height of her center of mass above the datum line at the end of the skill.

The changes in kinetic energy (T) did not completely follow an expected pattern (Fig. 38). Due to a negative angular velocity (Wr) at the beginning of the skill AD's action produced a drop in kinetic energy (T) as her body rose in the initial part of the straddle-in action. As

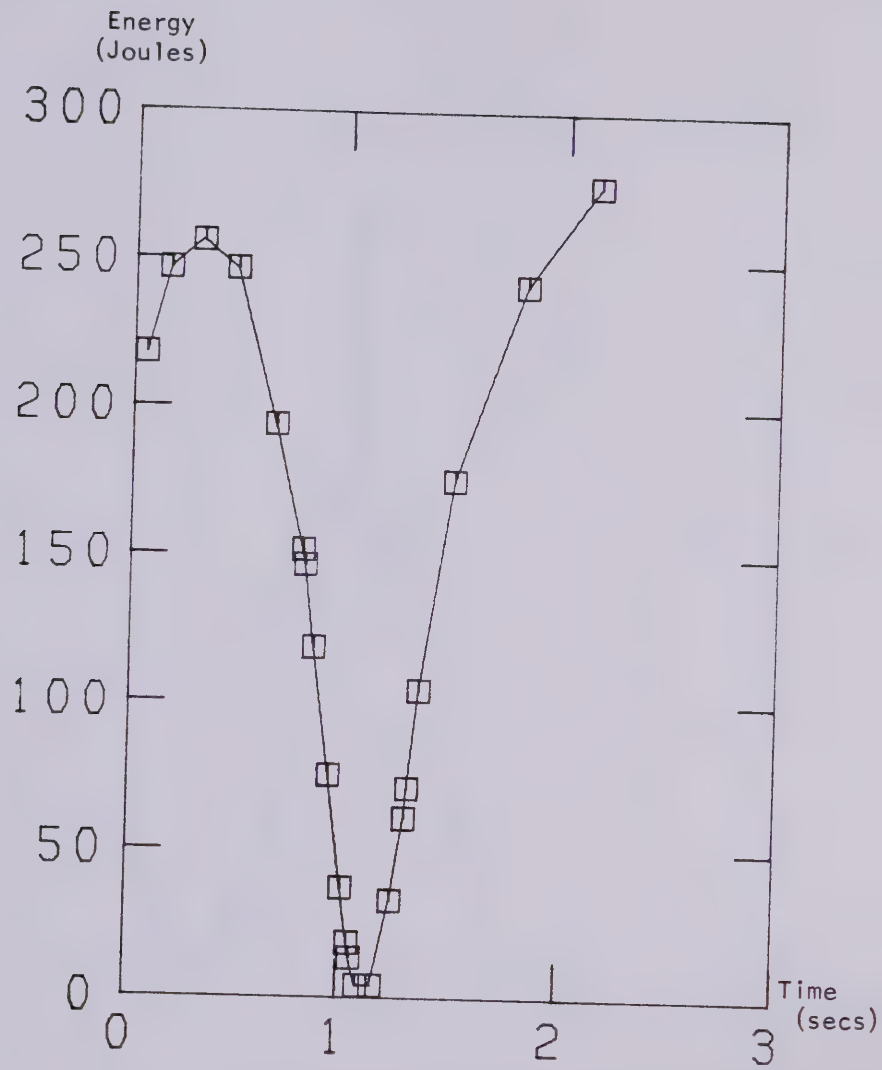

Figure 37. Potential Energy for Subject AD.

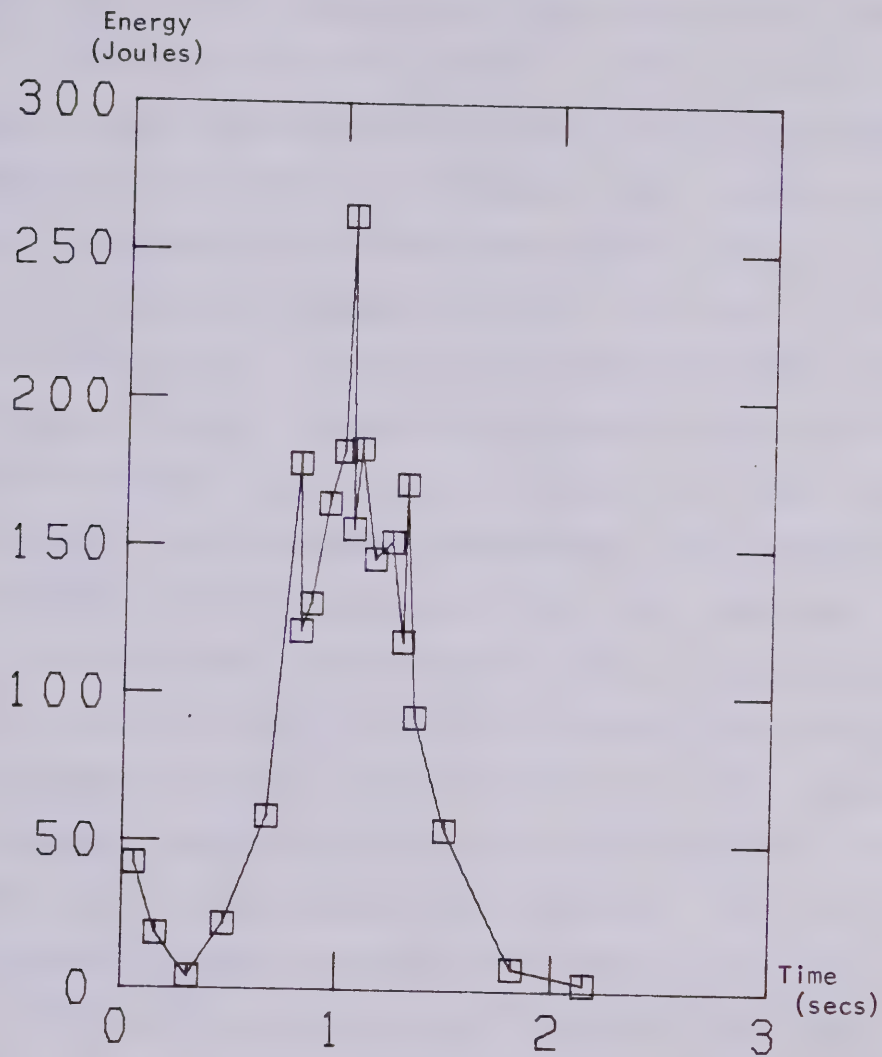

Figure 38. Kinetic Energy (T) for Subject AD.

gravity caused AD to begin to displace the center of mass in a positive direction the measures of kinetic energy (T) increased through the remainder of the straddle-in. During Phase 2, as AD passed the rail on the down swing, she performed a rapid extension of the arms at the shoulders, thus causing a great amount of rotation about her own center of mass. The measure of rotational kinetic energy at this point is at its second highest level for the total Stalder at 178.20J (Fig. 39). There was a corresponding drop in the translational kinetic energy at this point indicating that the rotation caused a change in the center of mass which would produce less downward displacement than expected as well as change the horizontal path (Fig. 40). Measures for angular velocity (Wcm) during Phase 2 show a large negative measure (-23.26 rads/sec) of angular velocity (Wcm) followed by an increase in angular velocity (Wcm) to 43.22 rads/sec. These changes produced a drop in the kinetic energy (T) at this point in the down swing. The remainder of the down swing produced greater measures of kinetic energy (T) to a maximum of 261.60J at the bottom of the swing (Fig. 41).

The maximum amount of kinetic energy (T) produced (261.60J) was greater than the amount of potential energy possessed by AD at the beginning of the skill (255.87J) (Fig. 42). Because potential energy is measured with respect to vertical displacements primarily, and kinetic energy (T) is affected by rotations of the gymnast about her own center of mass as well as the translational changes,

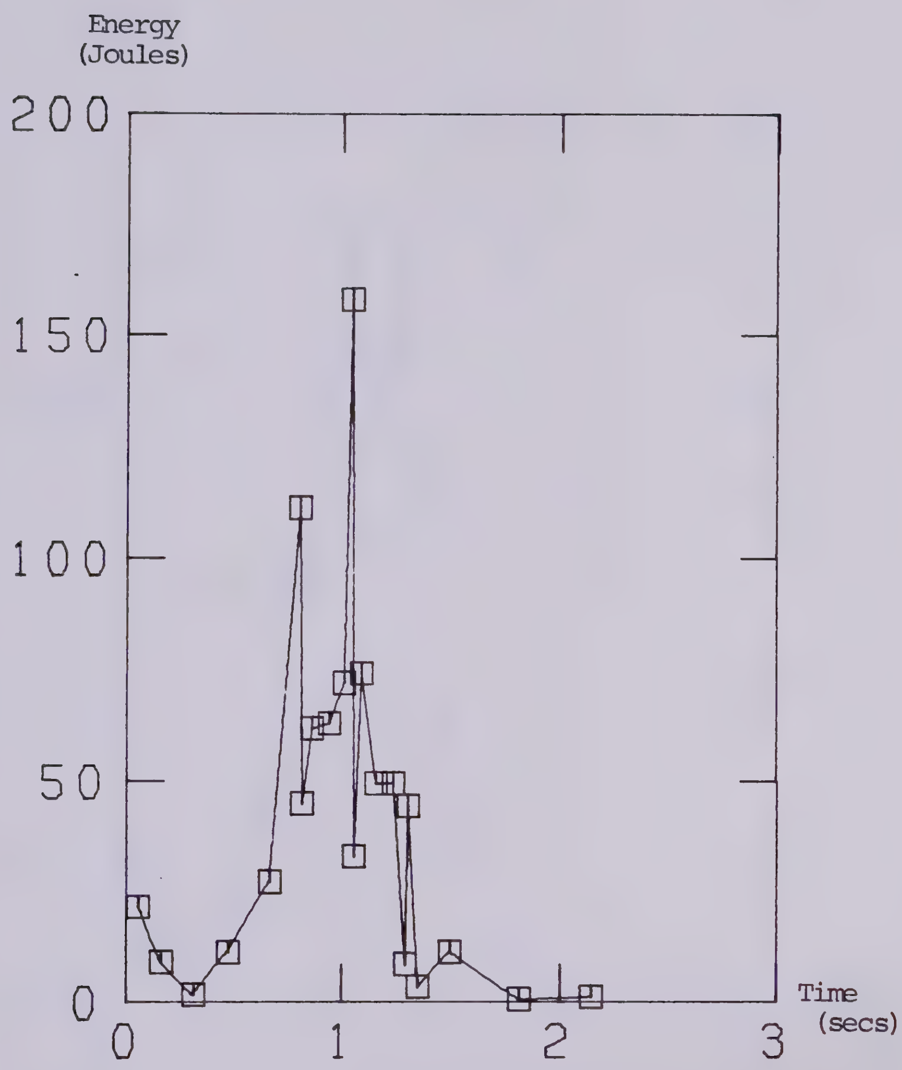

Figure 39. Rotational Kinetic Energy for Subject AD.

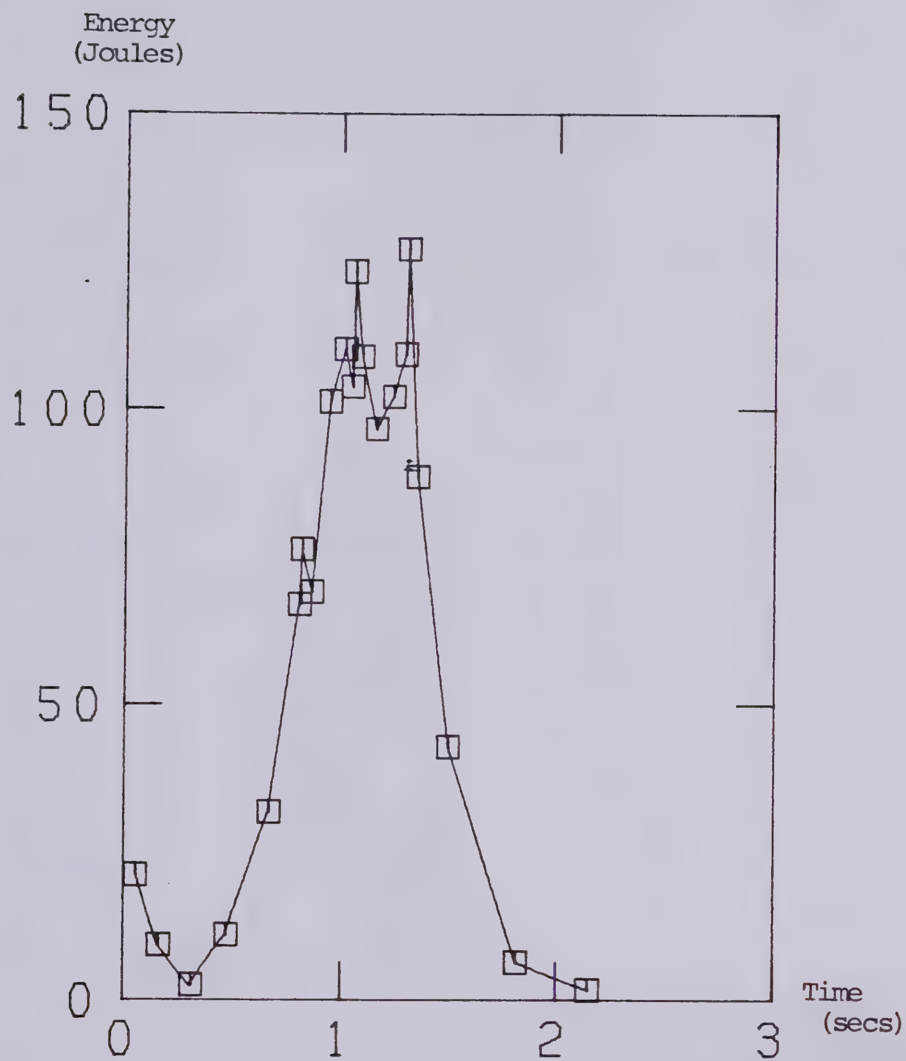

Figure 40. Translational Kinetic Energy for Subject AD.

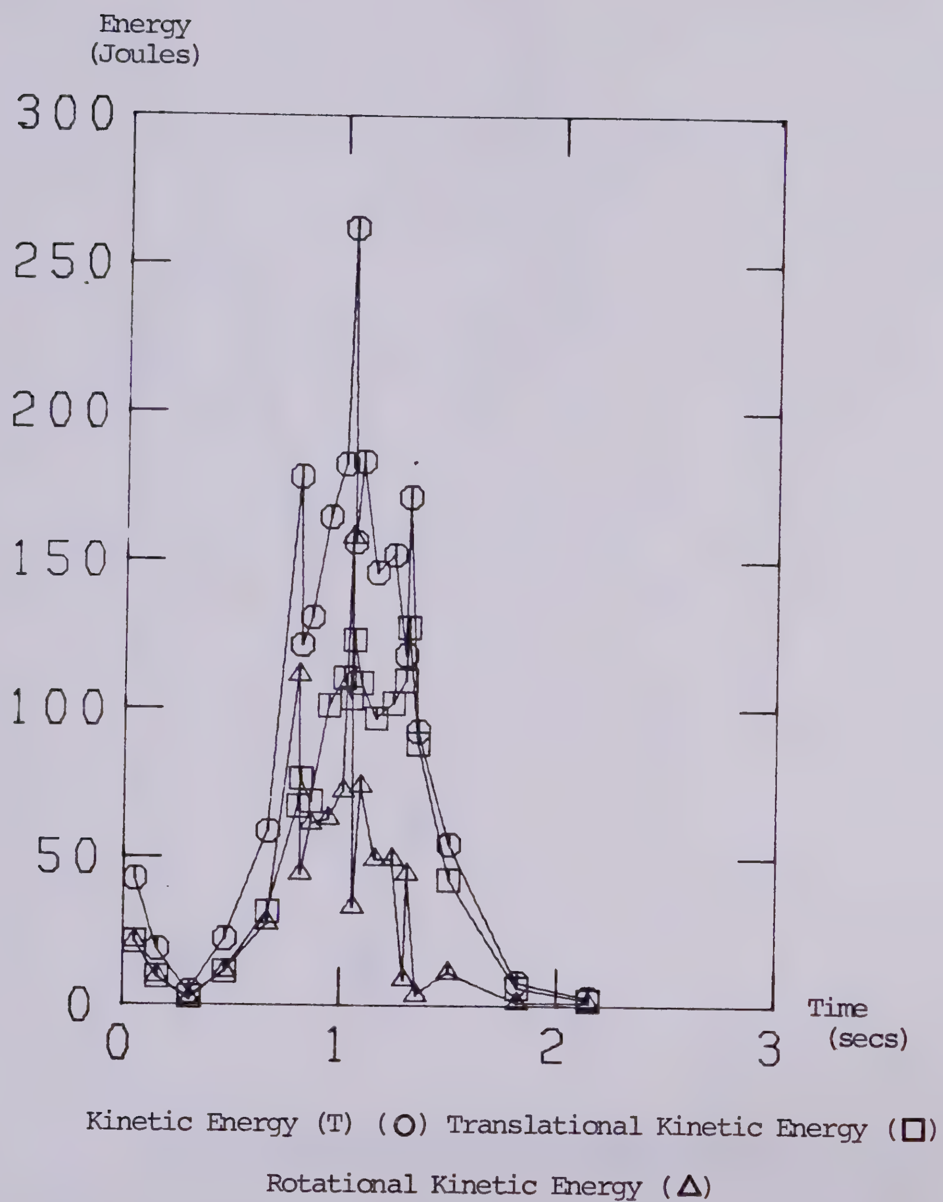

Figure 41. Relationships Among Kinetic Energy (T), Translational Kinetic Energy, and Rotational Kinetic Energy for Subject AD.

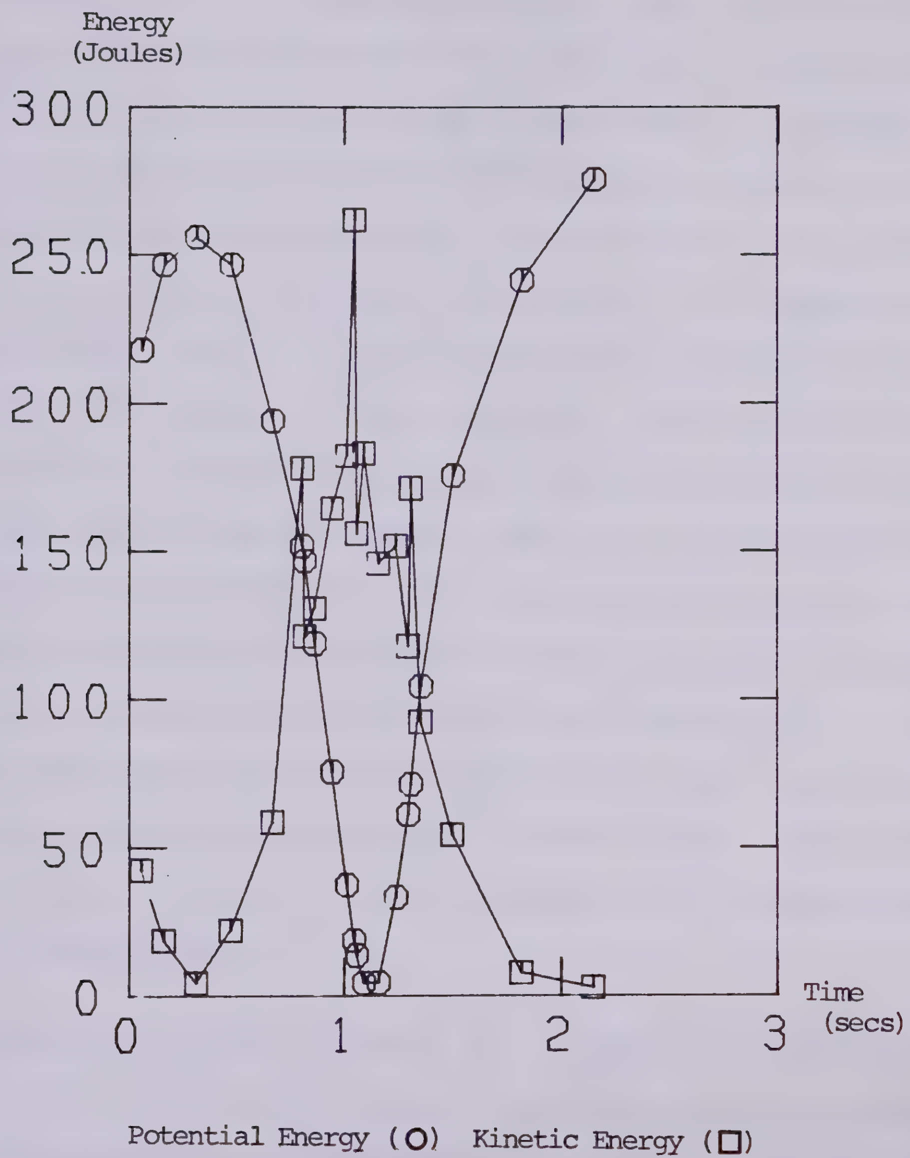

Figure 42. Relationship Between Potential Energy and Kinetic Energy (T) for Subject AD.

differences in kinetic energy (T) due to large measures of rotational kinetic energy, this difference can be explained. The greater amount of kinetic energy (T) can be attributed to the very large measures of rotational kinetic energy (157.80J) obtained at the bottom of the swing. Although a small drop in translational kinetic energy occurred at this point, the amounts of rotational kinetic energy were greater through the entire bottom swing than the measures of translational kinetic energy and had a strong effect on the total kinetic energy of the system. The measures of translational kinetic energy and rotational kinetic energy show that while AD rotated about the rail, the amount of rotational energy about her own center of mass was equal to or greater than the translational kinetic energy. The small measures of moment of inertia (Ir) produced by AD's performance were not great enough to allow for large linear velocities of the center of mass. These small horizontal and vertical velocities kept measures of translational kinetic energy small.

Measures of kinetic energy (T) dropped off throughout the up swing except for a slight increase in kinetic energy (T) at the start of the straddle-out action. The action performed by AD to aid in her up swing was to forcefully flex the upper extremity at the elbows. This method of shortening the radius of rotation, produced the result of decreasing the moment of inertia and thus increasing angular velocity (Fig. 2p-v). The increase in kinetic energy (T),

however, was insufficient to allow AD to swing to a final position. The final measure of rotational kinetic energy of 3.10J had to have been produced through muscling performed by AD as the measure of angular momentum (Hr) at the completion of the skill was -.80Kg.m2/s indicating a negative measure of angular velocity (Wr) and a downward displacement caused by gravity.

Deflections of the Rail

The action of the gymnast circling the rail and internal changes in the system by the gymnast altering her body position, coupled to have an affect on the rail itself. The rail deflected in the direction of the applied load. Being elastic in nature, as a requirement of the F.I.G., the rail returned to its original position when unloaded. The recoil action of elastic properties are instantaneous as loads are removed. The action of recoil could have produced enough force to enhance the angular velocity (Wr) of the gymnast, and thus, all other variables containing measures of angular velocity (Wr) (i.e. angular momentum (Hr) and kinetic energy (T)).

Figure 43 is an X Y plot of rail deflections for the total Stalder for JM. The deflection pattern caused by JM's performance indicated large horizontal deflections during the down swing and up swing. However, the largest measure of deflection was downward during the bottom swing. The large measures of horizontal and vertical velocity of the

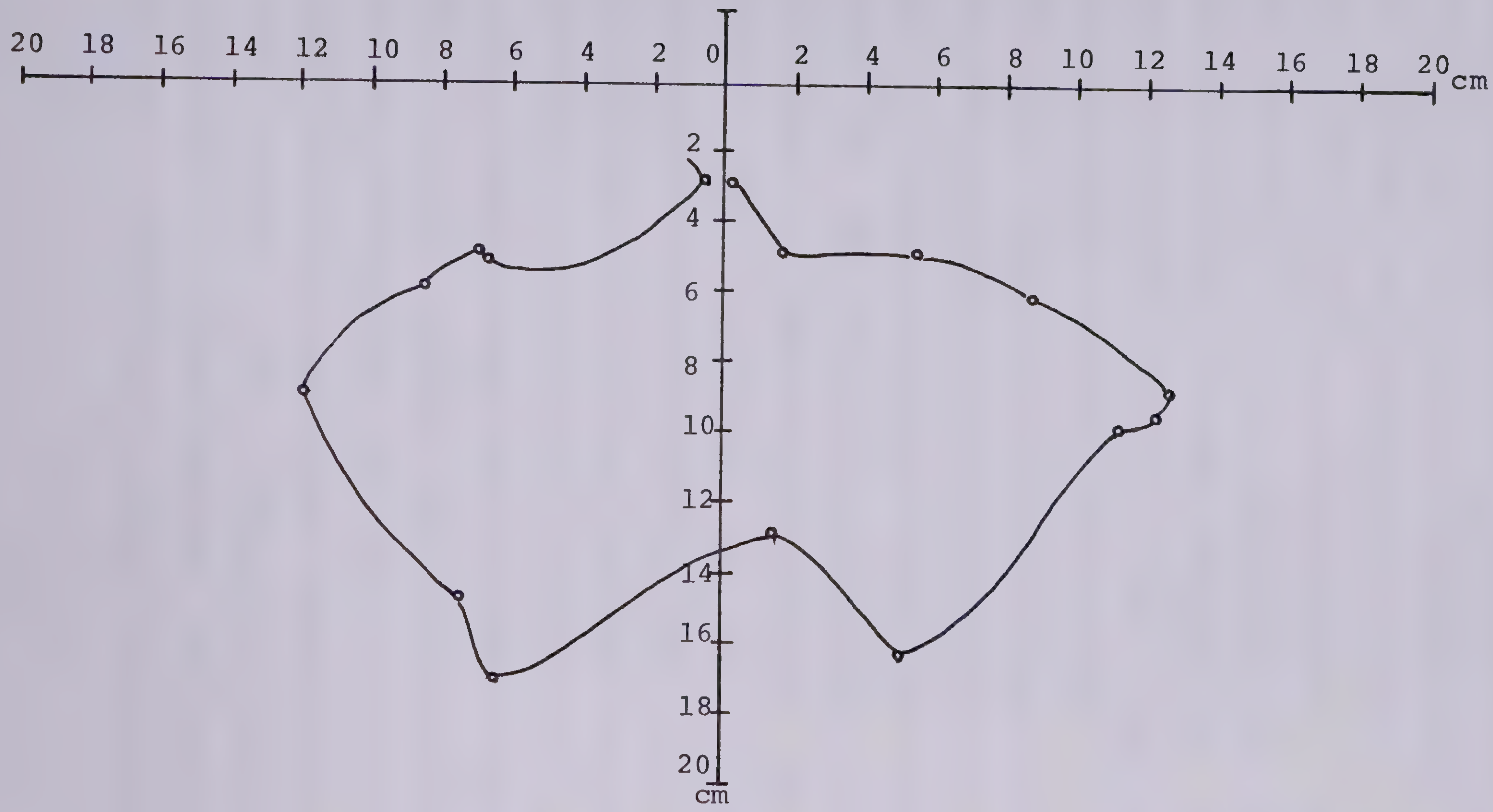

Figure 43. X Y Plot of Rail Deflections for Subject JM

center of mass indicated by large measures of translational kinetic energy contributed to the deflections. The mean X, Y, and linear rail deflections in all phases of the Stalder performance for JM are listed in Table 11. Just prior to the beginning of the bottoming action and through Phase 4 measures of X rail deflection decreased from 3.20cm to .41cm between frames 10 and 14. The recoil of the rail in the X direction occurring at this point coupled with small amounts of recoil in the Y direction (3.91cm to 3.56 cm) at the beginning of Phase 4 could have been a contributing factor to the increase in angular velocity (Wr) occurring at this point. The increased angular velocity (Wr) contributed to an increase in angular momentum (Hr) which provided JM sufficient force to deflect the rail in the X and Y directions at the start of the up swing. Large decreases in Y deflections of the rail (4.34cm to 2.59cm) occurred immediately prior to frame 17. It was at this point in the up swing that JM's second major increase in angular velocity (Wr), angular momentum (Hr), and kinetic energy (T) occurred. Recoil of the rail primarily in the Y direction upward enhanced the velocity and momentum of the swing. The recoil, inward in the X direction, would also aid in bringing JM to a position above the rail without the necessity of elbow flexion or other muscling actions.

Table 11. Mean Measures of X, Y, and Linear Rail Deflections in cm for all Phases of Skill Execution for Subject JM.

PHASE	X	Y	LINEAR
1	.67	2.91	3.02
2	7.42	5.11	9.03
3	9.55	5.18	11.12
4	6.98	14.92	16.26
5	5.52	14.70	15.70
6	12.05	9.18	15.14
7	7.39	6.51	10.11

Small measures in translational kinetic energy throughout the Stalder performance of AD were reflected in the small amounts of both X and Y rail deflections for the skill. The amounts of angular velocity (Wr) and kinetic energy (T) were small. This indicates less force against the rail to deflect it. The mean values of X, Y, and linear rail deflections for all phases for AD are presented in Table 12. Figure 44 is a plot of X and Y deflections of the rail. Loads on the rail sufficient to produce much deflection did not occur until the lower portion of the down swing when angular velocity (Wr) and angular momentum (Hr) were reaching maximum levels. X deflections decreased from 2.88cm to .05cm through the bottomswing and the start of the up swing. This recoil produced force to increase the angular velocity (Wr) at this point. Continued increase in Y deflection downward from .41cm to 2.82 cm took place during this phase. Recoil of the rail in the Y direction upward occurred just prior to the beginning of the straddle-out action. This enhanced the angular velocity (Wr) at this

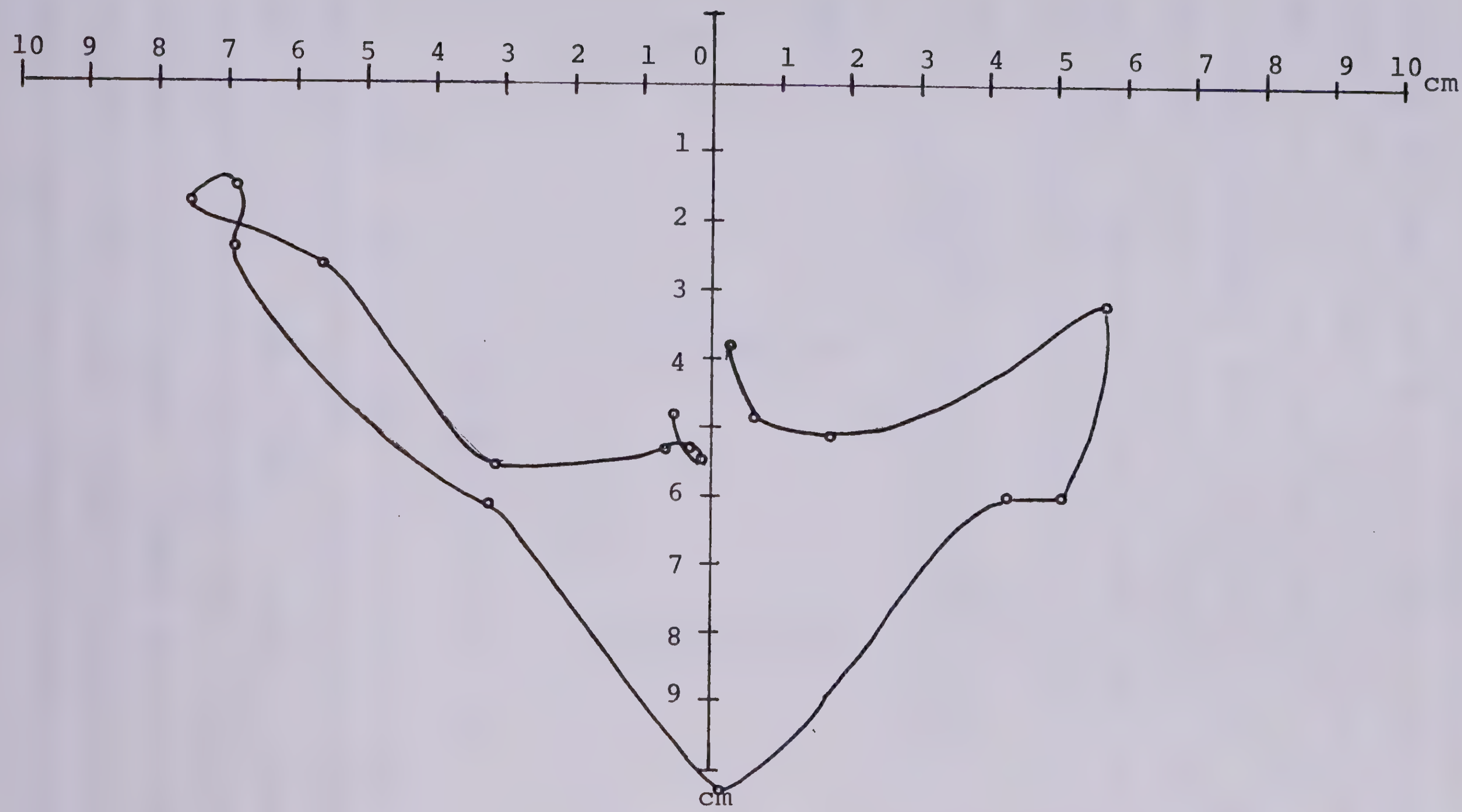

Figure 44. X Y Plot of Rail Deflection for Subject AD

point. Recoil of the rail in the X direction was small through the beginning of the up swing. Not enough force was produced by this recoil to aid AD in bringing her center of mass closer to the original position of the rail. Elbow flexion performed by AD at this point in the up swing was necessary to bring her body in toward the rail for the final position. Initiation of the straddle-out action took place with the upward recoil of the rail for both JM and AD.

Table 12. Mean Measures of X, Y, and Linear Rail Deflections in cm for all Phases of Skill Execution for AD.

PHASE	X	Y	LINEAR
1	.61	4.33	4.37
2	.29	5.31	5.38
3	1.91	4.80	5.70
4	7.11	1.88	7.36
5	4.91	4.37	7.83
6	4.30	5.63	7.11
7	3.03	4.84	5.99

STATISTICAL ANALYSIS OF DATA

All 14 subjects were competitive gymnasts. Subject participation in some level of competitive gymnastics ranged from 1.5 to 7 years ($\overline{x}$=3.7 years). Class I or Elite competitive levels had been held over a range of one week to five years ($\overline{x}$=1.9 years). There were no statistically significant differences between the groups on the number of years in competition or competitive classification.

Judges Rankings and Performance Grouping

The ranking of filmed trials by the panel of expert judges was carried out to divide performances into groups for the purpose of subjecting the data to a one way analysis of variance. This statistical treatment was used to determine if any significant differences existed among successful Stalder performances. The trials were ranked relative to one another and four groups were established by equally dividing the 28 trials. There was strong consensus among the judges as to which trials were the seven best and seven poorest performances. They agreed that the middle ranked performances were all fairly similar in execution, therefore, there was less consistency in the exact ranking order of the middle 14 trials than for the top and bottom groups of seven. Trials which were eventually ranked in either the excellent performance (Group I) or poorer performance (Group IV) groups were ranked within a range of 6.5 ranking positions by all the judges. The trials which were eventually ranked in the middle two groups were placed in an order within a range of eight ranking positions by all the judges. Table 13 displays the specific judges rankings for all trials as they were viewed on the film. A multiple correlation of R=+.610 between the final overall ranking and the total judging panel showed that there were strong similarities among the individual judges rankings. All nine judges had placed five of the top seven trials within Group I. Of the remaining two trials which were included in Group

I by the overall ranking, eight judges ranked on trial within the top seven with the remaining judge ranking that trial eighth. The last trial ranked within Group I had five judges place it within that group, three judges ranked it eighth and one judge ranked it tenth overall.

For the poorer performances all nine judges placed the two lowest trials in Group IV. Three other trials ranked in Group IV were placed there originally by eight of the nine panel members with the final judges ranking them low in Group III. Two trials were ranked in Group IV by four and six judges respectively with all other rankings occurring in Group III.

The final ranking also indicated that nine of the 14 subjects had both trials ranked within the same group. Three of these subjects had both trials ranked in Group I. The remaining gymnast who had one trial in Group I had her second trial ranked eighth overall. A similar situation existed within Group IV, however the subject with only one trial ranked in Group IV had her second trial ranked eighteenth overall. The trial numbers in rank order by each judge and same-subject performances are shown in Table 14.

Table 13. Individual Judges Ranking of Viewed Trials.

JUDGE #	1	2	3	4	5	6	7	8	9
TRIAL # ON FILM	RANKING								
1	12	12	10	11	9	14	7	8	9
2	27	24	28	22	24	25	21	25	25
3	24	25	26	23	23	24	18	26	23
4	26	27	27	25	26	23	27	24	24
5	28	28	24	28	28	26	24	28	28
6	11	13	15	12	10	21	15	9	11
7	4	3	5	3	6	6	5	5	1
8	25	22	22	21	27	27	22	23	27
9	23	21	11	27	21	16	20	18	26
10	1	2	4	1	3	7	6	6	3
11	22	26	18	24	20	19	23	20	22
12	5	6	1	4	2	1	2	2	5
13	16	15	13	17	12	11	12	15	14
14	13	14	20	16	13	20	9	11	16
15	8	7	7	8	5	5	10	7	8
16	20	20	23	18	16	22	17	17	15
17	6	4	6	5	8	4	3	3	6
18	14	11	9	13	7	8	8	10	17
19	7	9	8	7	11	17	13	14	7
20	15	23	19	14	14	13	19	16	12
21	9	10	14	10	19	12	16	12	10
22	19	19	21	20	18	15	25	21	20
23	18	18	16	19	17	18	26	19	19
24	21	17	25	26	25	28	28	27	21
25	10	8	12	9	15	9	11	13	13
26	17	16	17	15	22	10	14	22	18
27	3	5	3	6	1	2	1	1	4
28	2	1	2	2	4	3	4	4	3

Table 14. Trial Ranking By Judge According to Performance Ranking With Final Overall Ranking, Groups and Same Subject Performances Indicated

PERFORMANCE RANKING	JUDGE # 1	2	3	4	5	6	7	8	9	OVERALL FINAL RANKING (TRIAL #)
	TRIAL # ON FILM									
1	10	28	12	10	27	12	27	27	7	(28)
2	28	10	28	28	12	27	12	12	28	(27)
3	27	7	27	7	10	28	17	17	10	(10)
4	7	17	10	12	28	17	28	28	27	(7)
5	12	27	7	17	15	15	7	7	12	(17)
6	17	12	17	27	7	7	10	10	17	(15)
7	19	15	15	19	18	10	1	15	19	(12)
8	15	25	19	15	17	18	18	1	15	(1)
9	21	19	18	25	1	25	14	6	1	(19)
10	25	21	1	21	6	26	15	18	21	(18)
11	6	18	9	1	19	13	25	14	6	(25)
12	1	1	25	6	13	21	13	21	20	(21)
13	14	6	13	18	14	20	19	25	25	(6)
14	18	14	21	20	20	1	26	19	13	(13)
15	20	13	6	26	25	22	6	13	16	(14)
16	13	26	23	14	16	9	21	20	14	(20)
17	26	24	26	13	23	19	16	16	18	(26)
18	23	23	11	16	22	23	3	9	29	(16)
19	22	22	20	23	21	11	20	23	23	(23)
20	16	16	14	22	14	14	9	11	22	(22)
21	24	9	22	8	9	6	2	22	24	(9)
22	11	8	8	2	26	16	8	26	11	(11)
23	9	20	16	3	3	4	11	8	3	(3)
24	3	2	5	11	2	3	5	4	4	(8)
25	8	3	24	4	24	2	22	2	2	(24)
26	4	11	3	24	4	5	23	3	9	(2)
27	2	4	4	9	8	8	4	24	8	(4)
28	5	5	2	5	5	24	24	5	5	(5)

Subject-Specific Variables

Although apparent differences existed between JM and AD on the subject-specific variables of competitive levels and anthropometric measures, these differences existed only between the individual subjects. For the variables: total years in competition, years as a Class I or higher gymnast, age, height, mass, mean grip strength, upper extremity length, trunk length, lower extremity length, active shoulder flexibility and active hip flexibility the analysis of variance indicated that there were no significant differences between any of the groups on any of these variables. Significant differences occurring between groups in kinematic and kinetic variables cannot be attributed to differences in mass or segment lengths. Appendix F contains all the measurements for these variables for all subjects.

Statistical Analysis of Biomechanical Data

Temporal Data

The analysis of variance showed that there were no significant differences between the groups on time of the total Stalder ($\overline{x}$=2.48 seconds), time of the down swing ($\overline{x}$= 1.36 seconds), or time of the up swing ($\overline{x}$=1.12 seconds). The analysis of variance on the temporal data for each of the seven phases of skill performance showed that no significant differences existed between the groups for Phases 1-6. The straddle-out action, Phase 7, however, was

completed in significantly different amounts of time by Groups I and IV (3 F 26 = 3.37). Group I trials, averaging a straddle-out time of .74 seconds, performed this action in significantly less time than the Group IV trials ($\bar{x}$=.96 seconds). The temporal data showing the difference between Group I and IV for Phase 7 is presented in Table 15.

Table 15. Temporal Data in Seconds for All Trials in Phase 7.

	ALL TRIALS	GROUP I	GROUP IV
RANGE	.57 - 1.40	.57 - .89	.83 - 1.40
MEAN	.84	.74	.96
S.D.	.15	.11	.20

Although there was not a significant difference between the groups for the total time of the up swing, the difference during Phase 7 may have contributed to the significant correlation (r=+.383) obtained between the overall ranking and the time of the up swing. This correlation shows a positive relationship between the faster up swing and the higher ranking trials.

Displacement of the Center of Mass about the Rail

All 28 trials completed were successful Stalders. There was no significant difference between the groups on the total displacement of the center of mass about the rail for the total skill. The difference between Phase 1

displacement for JM and AD was indicative of the difference between their respective groups. The position of the initial cast position contributed to a significant difference (3 F 26 = 6.31) between Group I and Group IV on the displacement of the center of mass during Phase 1 or the straddle-in action. Group I averaged 1.26 radians (72.19 degrees) of center of mass displacement during Phase 1. Group IV showed an average displacement of .92 radians (52.71 degrees) of the center of mass for the same phase (Fig. 45). The specific differences between the groups are shown in Table 16. There were no differences in displacement of the center of mass for the remaining phases.

Table 16. Displacement of the Center of Mass In Radians During Phase 1.

	ALL TRIALS	GROUP I	GROUP IV
RANGE	.71 - 1.36	1.14 - 1.36	.71 - 1.20
MEAN	1.11	1.26	.92
S.D.	.30	.005	.04

Articular Displacements and Moments of Inertia

Differences noted in the performance techniques of JM and AD respecting changes in hip and shoulder angles and the consequential changes in moments of inertia were characteristic of the performances of their respective groups. The analysis of variance revealed significant differences in certain shoulder and hip angle displacements

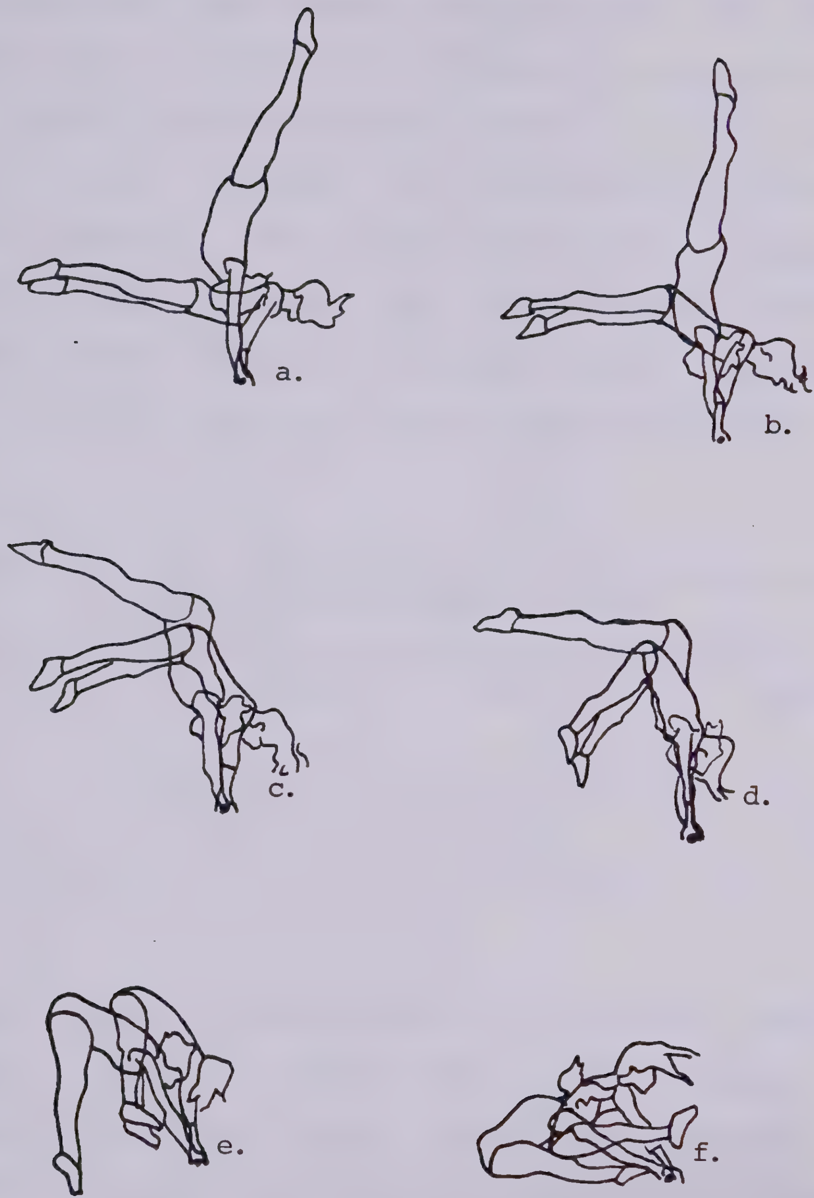

Figure 45. Frame by Frame Comparison of Body Positions for Subjects JM and AD During the Straddle-in (Phase 1).

and in most measures of moments of inertia for phases of skill execution. The overall range of motion for shoulder extension was a significant difference in the performances of the highest and lowest ranked groups (3 F 26 = 5.58). Group I trials averaged 1.40 radians (80.00 degrees) of shoulder extension while Group IV trials averaged 2.04 radians (116.80 degrees) for the same action (Table 17). The lower ranked trials demonstrated, on the average, 20% more shoulder extension than the performances ranked highest.

Table 17. Range of Motion of Shoulder Extension in Radians for the Total Stalder

	ALL TRIALS	GROUP I	GROUP IV
RANGE	1.10 - 2.33	1.10 - 2.10	1.70 - 2.28
MEAN	1.68	1.40	2.04
S.D.	.13	.12	.06

The Pearson Product Moment Correlation showed the variable of overall judges ranking to be most highly correlated with the overall change in shoulder angle throughout the skill (r=+.664). A frame by frame comparison of the actual measures of shoulder extension displayed by JM and AD is presented in Figure 46. One difference to be noted is the extreme variation at the beginning of the skill in which JM had little change in shoulder angle while AD performed rapid shoulder flexion then extension through the

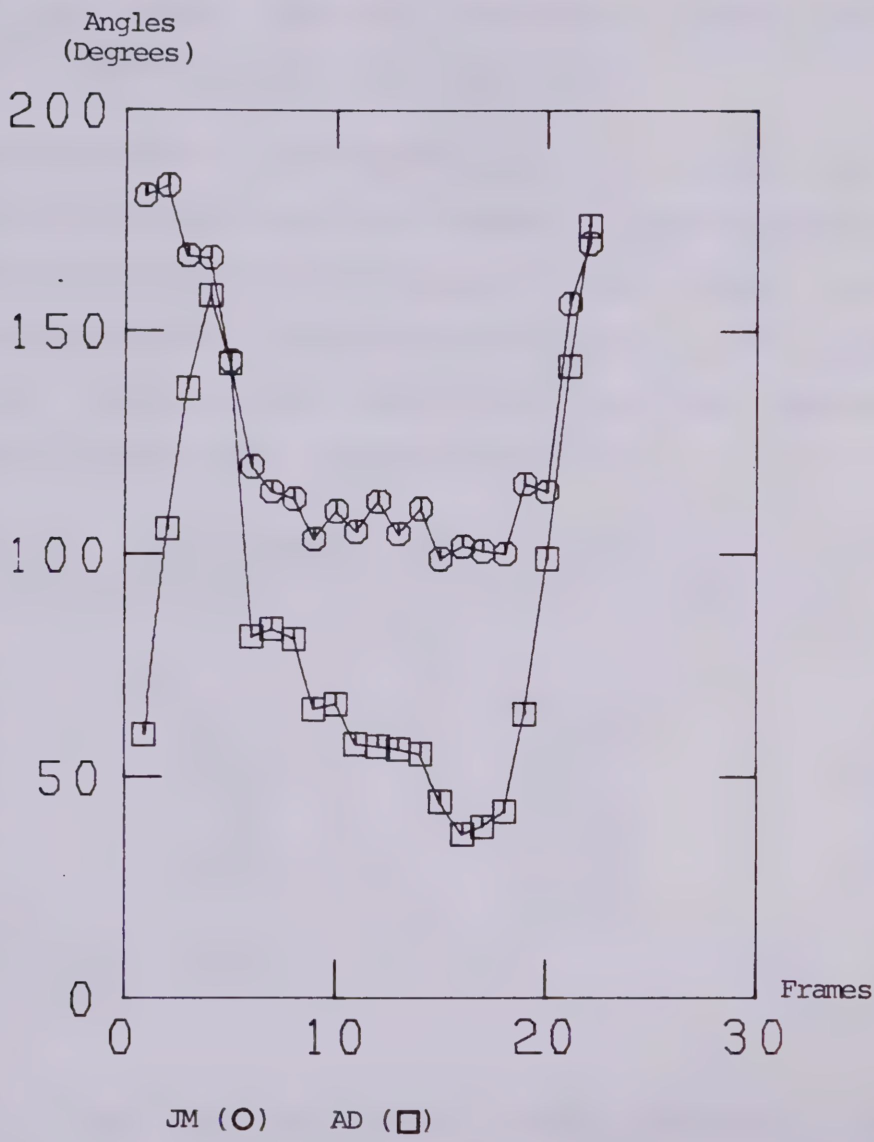

Figure 46. Frame By Frame Comparison of Shoulder Angles for Subjects JM and AD.

straddle-in action. Another difference occurred as AD demonstrated continual shoulder extension throughout the entire down swing while JM maintained a fairly constant shoulder angle throughout the bottom swing.

Analysis of the individual parts of the skill revealed significant differences in the amount of shoulder extension performed in all phases. Displayed in Table 18 are the mean measures of shoulder angles for both groups in all phases. Group IV had greater amounts of shoulder extension, therefore, the shoulder angles are smaller.

Table 18. Mean Shoulder Angles in Degrees for Group I And Group IV For All Phases of Skill Execution

PHASE	GROUP I	GROUP IV	F*
1	169.21	140.49	4.91
2	122.43	85.67	22.31
3	119.38	79.01	20.93
4	111.26	62.39	16.68
5	109.82	60.56	16.51
6	101.38	54.86	14.58
7	127.10	96.88	9.37

* 1 F 12 = 4.75 at .05

The actual change in shoulder angle occurring within each phase was different in only Phase 7 (1 F 12 = 17.97) the straddle-out action. Group IV had an average change in shoulder angle of 128.22 degrees. Group I had an average change of 74.91 degrees for this phase. Group I trials showed a position of less shoulder extension throughout the Stalder and had less shoulder flexion to perform to achieve

a handstand position than did Group IV trials, so this difference was not unexpected.

Although the patterns of hip flexion between JM and AD were quite similar (Fig. 47), the total range of hip flexion occurring throughout the skill also represented a significant difference between the highest and lowest ranked groups ($_3F_{26} = 3.74$). The trials in Group I showed greater overall hip flexion than did Group IV trials (Table 19). On the average, Group I trials actually utilized more than 180 degrees ($\bar{x}$=182 degrees) of hip flexion while Group IV trials averaged just under full flexion with a mean change of 172 degrees.

Table 19. Range of Motion of Hip Flexion in Radians for the Total Stalder

	ALL TRIALS	GROUP I	GROUP IV
RANGE	2.71 - 3.52	3.02 - 3.40	2.71 - 3.17
MEAN	3.12	3.18	3.01
S.D.	.04	.02	.02

For the variables of moment of inertia (Ir) and moment of inertia (Icm), the analysis of variance revealed significant differences in many phases of skill execution. As presented previously, there were no differences between the groups for the variables of mass, upper extremity length, lower extremity length or trunk length. As moments

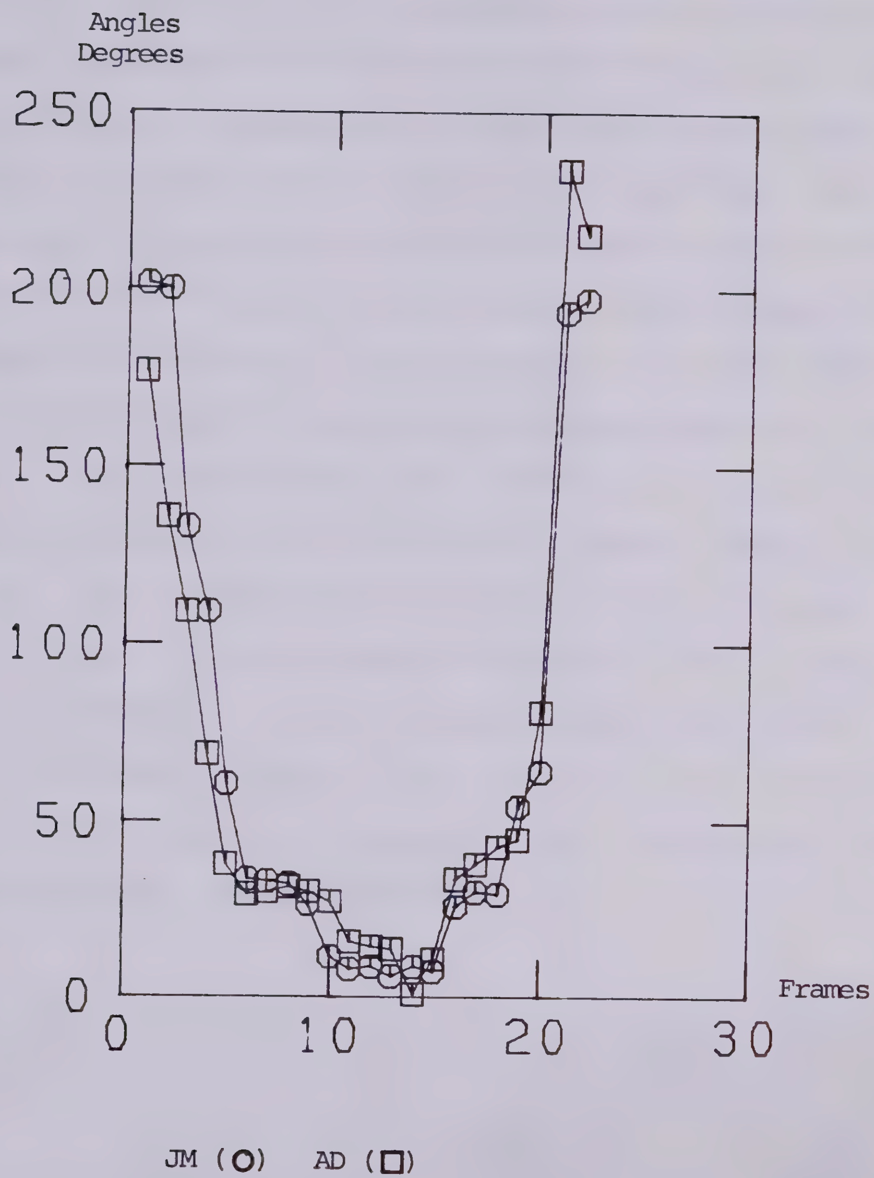

Figure 47. Frame By Frame Comparison of Hip Angles for Subjects JM and AD.

of inertia were calculated to be the $\Sigma miri2$, the actual position of the body, not the mass or length of the individual segments, was responsible for the differences in the moment of inertia (Ir) and the moment of inertia (Icm). The significant differences in shoulder extension for all phases of skill performance would be responsible for the differences in the radius of rotation about the rail of the center of mass. Figure 48 is a frame by frame comparison of the moment of inertia (Ir) for JM and AD. In most cases, JM had a measured moment of inertia (Ir) three times as great as AD. This difference was similar to the difference between the groups. The differences between Group I and Group IV for the measures of moments of inertia about the rail for Phases 1 - 6 are shown in Table 20. Only Phase 7 was not different in performance between the groups. The majority of trials completed the stalder in a handstand position. This would be responsible for a similarity, not a difference between Group I and Group IV.

Table 20. Mean Measures of Moments of Inertia (Ir) in Kg.m2 For Group I and Group IV in Phases 1 - 6

PHASE	GROUP I	GROUP IV	F*
1	23.25	10.64	12.30
2	14.27	5.94	17.63
3	13.95	6.18	16.59
4	15.10	8.25	7.21
5	14.36	7.77	8.86
6	14.21	7.76	8.41

* 1 F 12 = 4.75 at .05

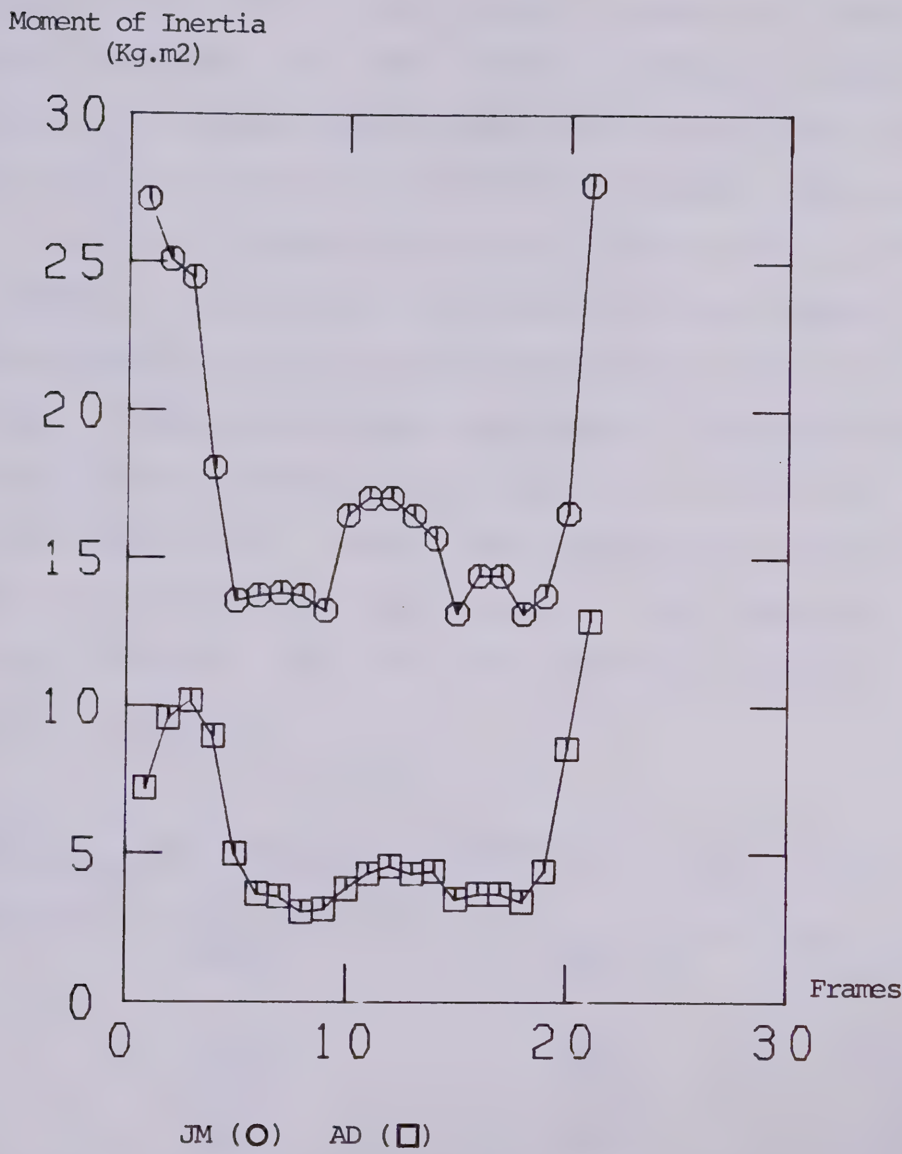

Figure 48. Frame By Frame Comparison of Moments of Inertia (Ir) Between Subjects JM and AD.

Differences also occurred for the variable of moment of inertia (Icm) in five of the seven phases of skill performance (Fig. 49). The greater amount of shoulder extension performed by the trials in Group IV would be responsible for decreasing the moment of inertia (Icm). Only Phases 6 and 7 showed no mean difference between the groups. Phase 6 and Phase 7 make up the total straddle-out action. All gymnasts would have performed various amounts of shoulder flexion and hip extension throughout these phases according to their individual techniques. The extension to the final position, which in most cases was close to the handstand position, would have eliminated differences between the groups during this action. The measures of moment of inertia (Icm) for the different phases are displayed in Table 21.

Table 21. Mean Measures of Moments of Inertia (Icm) in Kg.m2 for Groups I and IV for Significantly Different Phases

PHASE	GROUP I	GROUP IV	F*
1	2.95	1.43	13.56
2	1.36	.89	4.75
3	1.23	.79	5.63
4	1.25	.80	7.06
5	1.18	.75	6.73

* 1 F 12 = 4.75 at .05

Even though the straddle out action in Phase 7 did not show a difference in the average moment of inertia (Ir) between the groups, the moment of inertia (Ir) for the final

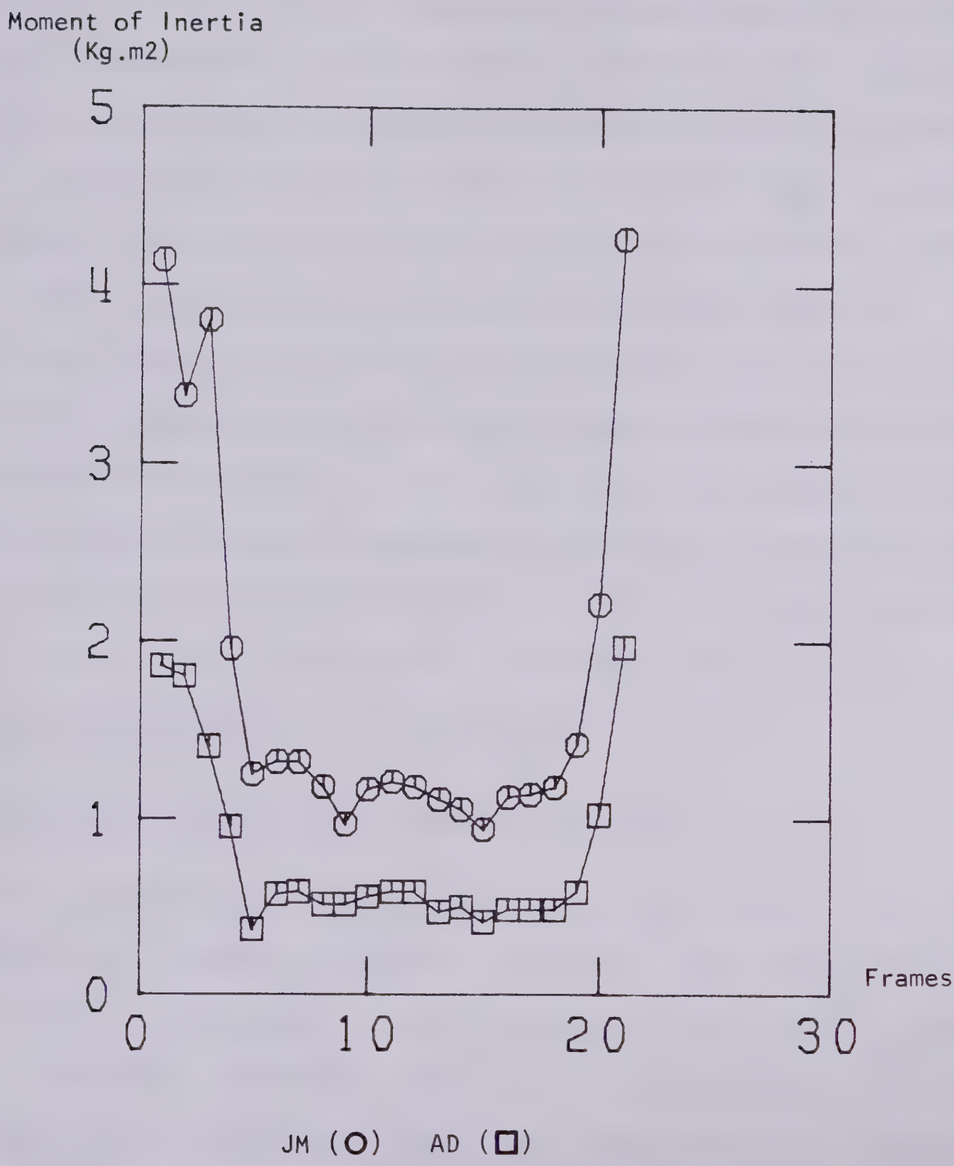

Figure 49. Frame By Frame Comparison of Moments of Inertia (Icm) Between Subjects JM and AD.

position did show a difference between the groups ($1\ F\ 12 = 5.36$). Group I had an average moment of inertia (Ir) of 27.82 Kg.m2 while Group IV had an average moment of inertia (Ir) of 15.58Kg.m2. The initial highest cast position showed an even greater difference in the moment of inertia (Ir) ($1\ F\ 12 = 18.98$) with Group I trials averaging a moment of inertia (Ir) of 29.65Kg.m2 in a handstand position while Group IV averaged 11.96Kg.m2 for the initial position. In most cases, less than handstand positions were attained. Deviations from a proper position included hyperextension of the lower extremities at the trunk and at the lumbar region of the back, and hyperflexion or insufficient flexion of the upper extremities at the shoulder. All of these actions would reduce the radius of rotation about the rail and decrease the moment of inertia (Ir).

Angular Velocity and Angular Momentum

The performance differences among the trials for the measures of average angular velocity (Wr) for the total skill ($\bar{x}$=2.51 rads/sec), angular velocity (Wr) for the down swing ($\bar{x}$=2.01 rads/sec), and angular velocity (Wr) for the up swing ($\bar{x}$=3.18 rads/sec) were not sufficient to produce differences between the groups. However the analysis of variance indicated a significant difference between Group I ($\bar{x}$=1.28 rads/sec.) and Group IV ($\bar{x}$=.85 rads/sec.) on the mean angular velocity (Wr) during Phase 1 ($3\ F\ 26 = 5.59$). As no difference existed on the variable of time for this

phase, the difference indicated in displacement of the center of mass would have caused the difference in angular velocity (Wr) to occur. The angular velocity (Wr) data for Phase 1 specifically is shown in Table 22. The similarities between JM and AD for the angular velocity (Wr) for the skill are illustrated in Figure 50. Figure 51 is a smoothed data curve of the mean angular velocity (Wr) for the phases of skill execution. Except for the extreme ends of the skill and during the bottom swing, AD generated greater measures of angular velocity (Wr) than did JM. These differences were representative of the groups with Group IV trials generating greater amounts of angular velocity (Wr) than Group I trials in most phases.

Table 22. Average Angular Velocity in Radians/Second During Phase 1.

	ALL TRIALS	GROUP I	GROUP IV
RANGE	.57 - 1.55	.96 - 1.55	.57 - 1.06
MEAN	1.05	1.28	.85
S.D.	.06	.04	.03

Changes in the angular velocity (Wcm) were different between the groups. During Phase 1, Group I had significantly greater measures of angular velocity (Wcm) than did Group IV (1 F 12 = 6.07). Through the rock back (Phase 3), bottom swing (Phase 4) and the beginning of the up swing (Phase 5), Group IV showed significantly greater

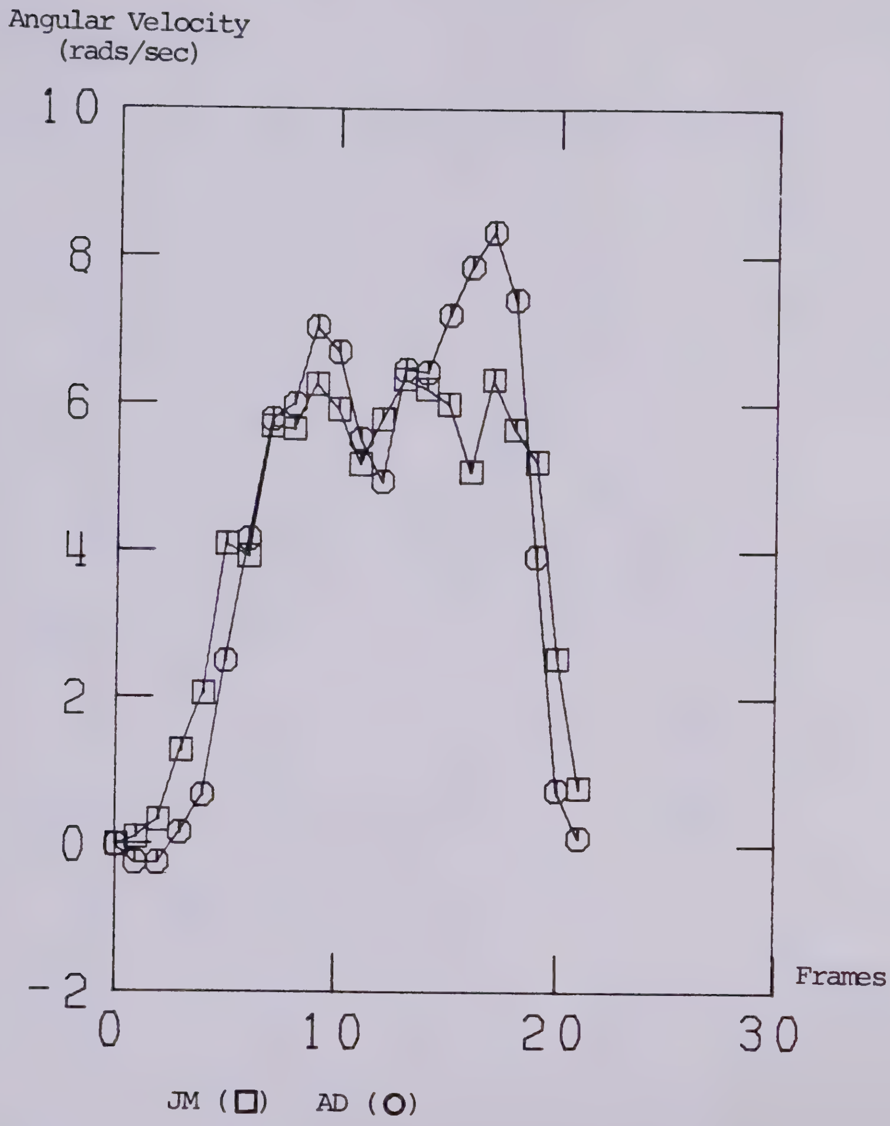

Figure 50. Frame By Frame Comparison of Angular Velocity (Wr) Between Subjects JM and AD.

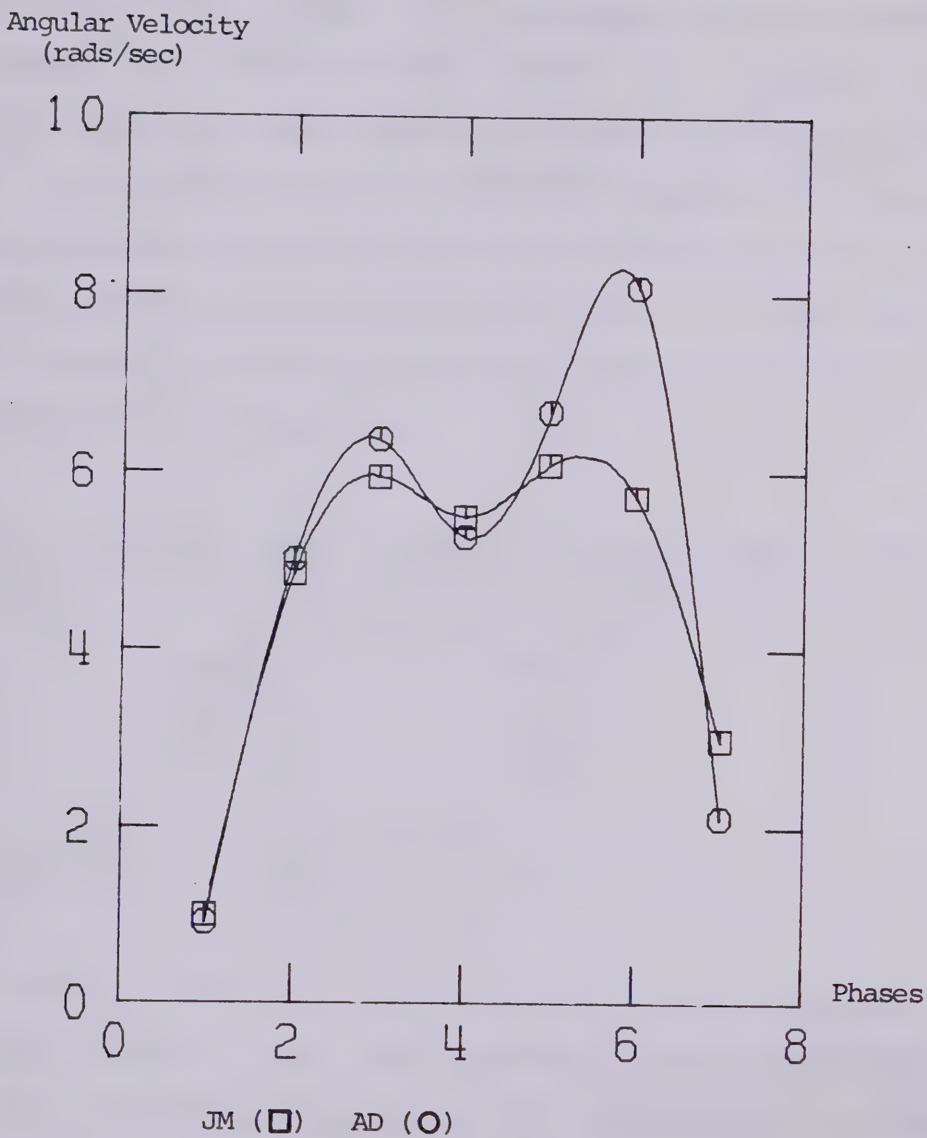

Figure 51. Phase By Phase Comparison of Angular Velocity (Wr) Between Subjects JM and AD.

measures of angular velocity (Wcm). Specific data for the angular velocity (Wcm) for these phases is presented in Table 23. The action of continuous shoulder extension throughout the entire down swing and bottom swing demonstrated by AD was characteristic of the trials in Group IV. The greater amount of shoulder extension by Group IV trials throughout the Stalder also would automatically cause greater rotation about the center of mass. A comparison of the changes in the angular velocity (Wcm) between JM and AD is illustrated in Figure 52.

Table 23. Mean Measures of Angular Velocity (Wcm) in Radians / Second for Groups I and IV in Significantly Different Phases

PHASE	GROUP I	GROUP IV	F*
1	5.26	.53	6.07
3	18.22	27.77	5.84
4	16.80	26.84	5.99
5	15.57	26.08	7.38

* 1 F 12 = 4.75 at .05

Group IV had, on the average, greater measures of angular velocity (Wr) than did Group I, but these measures were not significantly greater. The differences in moment of inertia (Ir) were significant. The combination of these variables produced differences in the amount of angular momentum (Hr). Group I had measures of angular momentum (Hr) averaging twice those of Group IV. These differences were significant in all phases of skill execution. The means and F values of angular momentum (Hr) for all phases

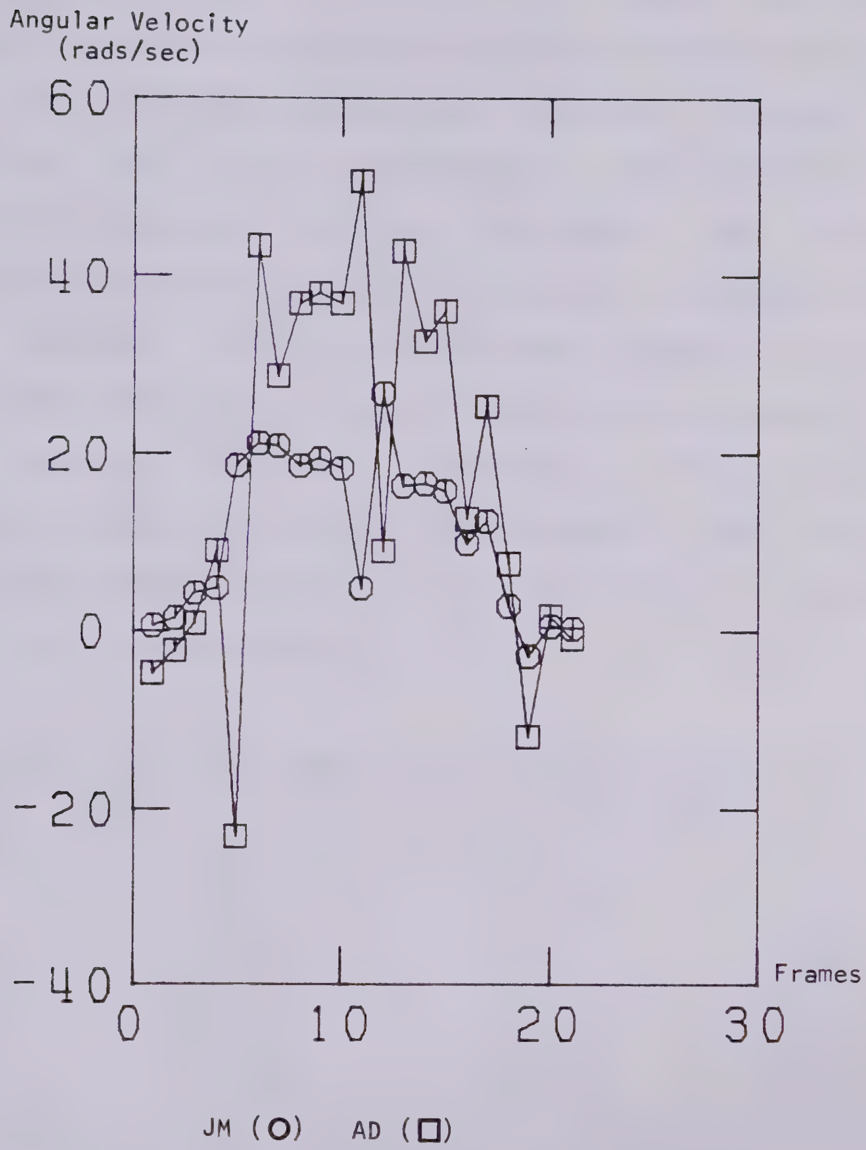

Figure 52. Frame By Frame Comparison of Angular Velocity (Wcm) Between Subjects JM and AD.

are presented in Table 24. Because only the measures of moment of inertia (Ir) were significantly greater in Group I than in Group IV, it is possible to assume that this variable caused the differences in angular momentum (Hr) to exist. The differences in shoulder extension between the groups was most likely responsible for the differences in the moment of inertia (Ir) and, therefore, were also a significant contribution to the differences occurring in the angular momentum (Hr). In almost every measure of angular momentum (Hr), JM produced nearly three times the amount of angular momentum than AD. Figure 53 is a frame by frame comparison of angular momentum (Hr) between JM and AD The patterns are similar reflecting the similarities in patterns between Group I and Group IV.

Table 24. Mean Measures of Angular Momentum (Hr) in Kg.m2/s for Groups I and IV for Phases 1-7

PHASE	GROUP I	GROUP IV	F*
1	31.32	6.45	52.26
2	77.78	42.36	20.34
3	85.62	49.05	18.82
4	106.27	63.90	11.44
5	90.08	60.98	10.35
6	87.28	53.11	10.73
7	55.09	28.78	25.36

* 1 F 12 = 4.75 at .05

The similarities in angular momentum (Hr) and angular momentum (Hcm) for both JM and AD were also similar in their

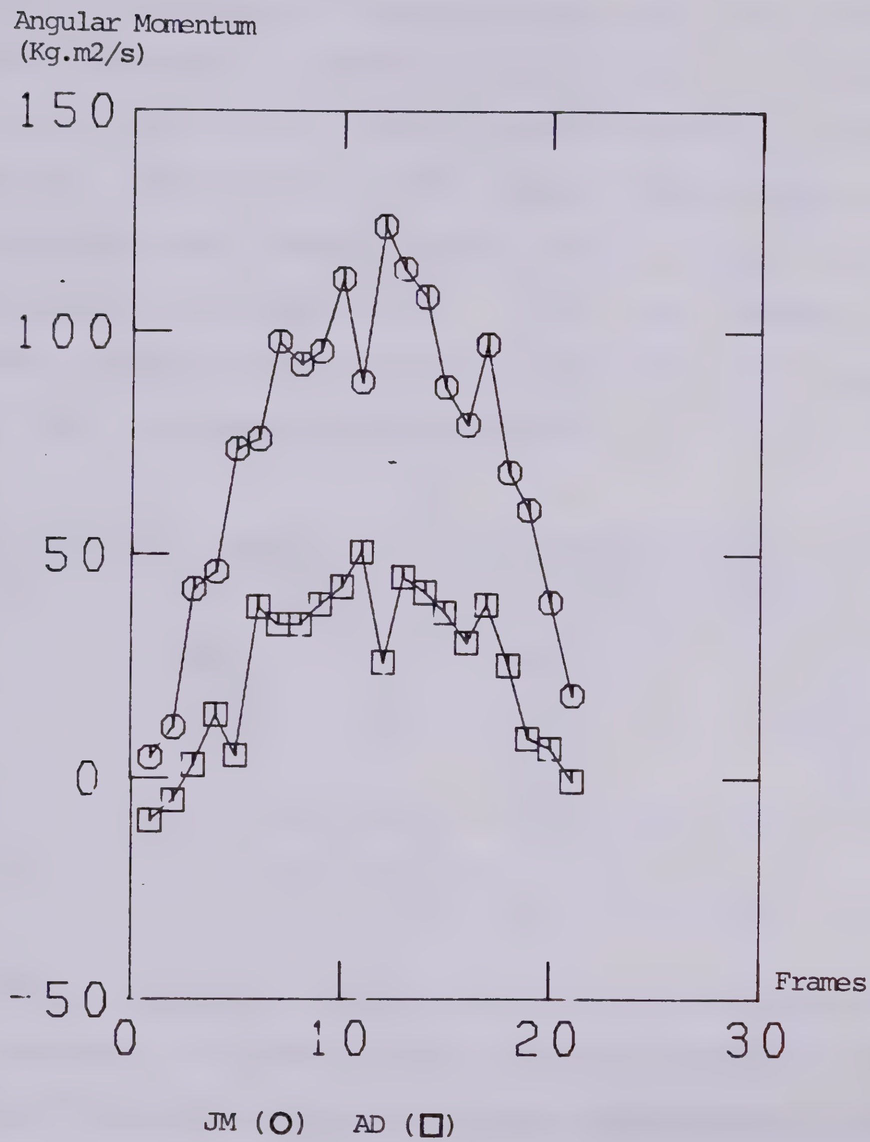

Figure 53. Frame By Frame Comparison of Angular Momentum (Hr) Between Subjects JM and AD.

groups. Angular momentum about the center of mass was different between the two groups except during the bottom swing and the beginning of the up swing (Fig. 54). Group I had greater measures of angular momentum (Hcm) in all phases except Phases 4, 5, and 6, where no differences existed. The greater measures of angular velocity (Wcm) produced by Group IV during these phases probably were responsible for no differences occurring here. The data showing the differences between the groups on the variable of angular momentum (Hcm) is displayed in Table 25.

Table 25. Mean Measures of Angular Momentum About the Center of Mass in Kg.m2/s for All Different Phases

PHASE	GROUP I	GROUP IV	F*
1	9.97	.88	36.59
2	24.92	17.84	11.37
3	21.51	18.89	5.53
7	5.72	2.31	7.38

* 1 F 12 = 4.75 at .05

Another difference between the performances of JM and AD was the amount of force against the rail produced in the down swing as measured indirectly from cinematographic data. JM produced more than twice the force against the rail during the bottom swing. Differences between Group I and Group IV for force against the rail when considered in multiples of body weight were significant (3 F 26 = 3.64). Group I trials were subjected to forces averaging 2.51 times their body weight (Kg) as they passed below the rail. Group

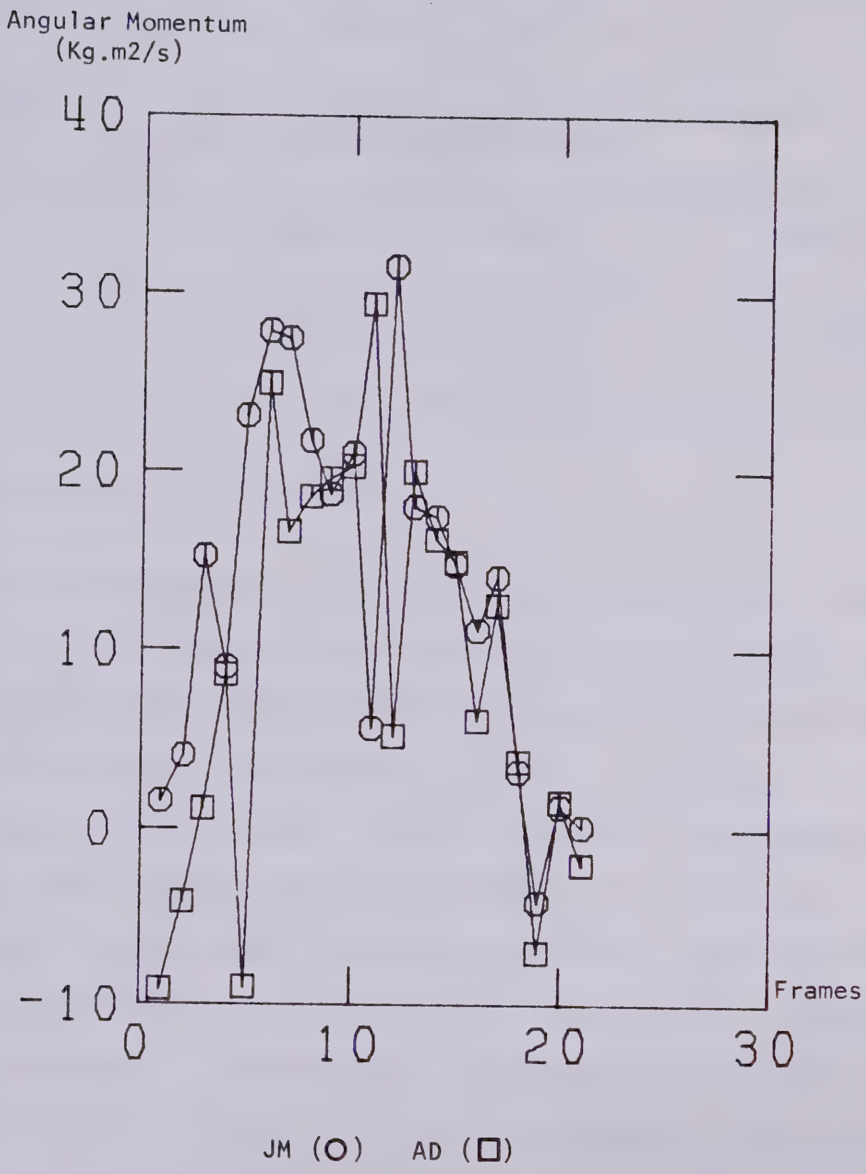

Figure 54. Frame By Frame Comparison of Angular Momentum (Hcm) Between Subjects JM and AD.

IV trials averaged a force equaling 1.69 times their body weight (Kg) during the bottom swing. The forces against the rail during Phase 4 are listed in Table 26.

Table 26. Force Against the Rail in Multiples Of Body Weight During Phase 4.

	ALL TRIALS	GROUP I	GROUP IV
RANGE	1.07 - 3.30	1.99 - 3.30	1.07 - 2.05
MEAN	2.18	2.51	1.69
S.D.	.22	.17	.13

Deflections of the Rail

Overall deflections of the rail caused by various forces in the Stalder were generally greater in X, Y, and linear measures for Group I than for Group IV. Measurements of rail deflections at Phases 2, 4, and 6 (points in the performance when loads were primarily horizontal or vertical) were subject to the analysis of variance. A significant difference (3 F 26 = 10.34) in rail deflection in the X direction during Phase 2 was obtained. Group I trials produced a horizontal deflection of the rail to a mean of 6.42cm. Group IV trials averaged 1.70cm of X deflection during Phase 2. Group IV trials had greater measures of Y deflections than X deflections at this phase, but these measures were not different between the groups. There were differences between JM and AD in rail deflection for the total Stalder (Fig. 55). Patterns in their groups were similar, with Group I trials showing greater overall

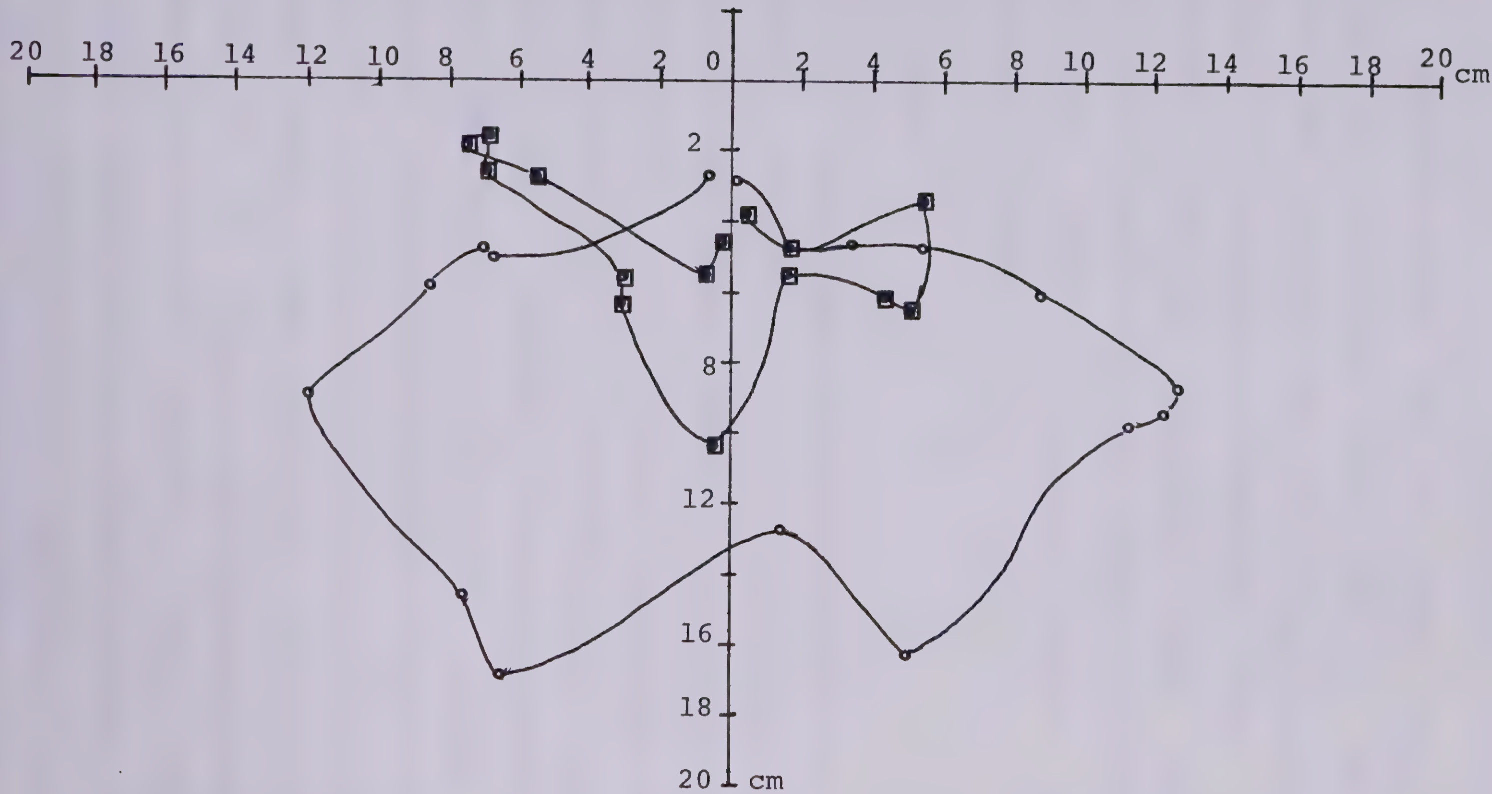

Figure 55. Comparison of Rail Deflection Patterns Between Subjects JM and AD

JM (○) AD (□)

amplitude in rail deflections in X and Y directions.

Forces against the rail during Phase 4 were nearly twice as great in Group I trials than in Group IV trials. This load against the rail produced a difference in the amount of rail deflection downward. Group I produced Y direction deflection averaging 10.37cm through Phase 4. This measure was significantly greater than Group IV trials (3 F 26 = 3.79) which averaged 4.73cm of rail deflection downward in Phase 4.

Energy

The highest positions of JM and AD at the start of the Stalder produced potential energy measures of 543.22J and 322.87J respectively. The large difference between the two performances is characteristic of the differences between their groups (Fig. 56). The measures of potential energy during Phase 1 produced a significant difference between Group I and Group IV (1 F 12 = 5.08). No other differences occurred in the down swing, but in the up swing in Phases 5,6, and 7 the measures of potential energy for Group I were significantly greater than the same phase measurements for Group IV. The differences in potential energy for these phases are presented in Table 27. These differences were probably caused due to general body position changes. Group I trials showed straight arms and greater overall amplitude in the up swing. Group IV trials characteristically showed almost full elbow flexion causing the body to move in toward

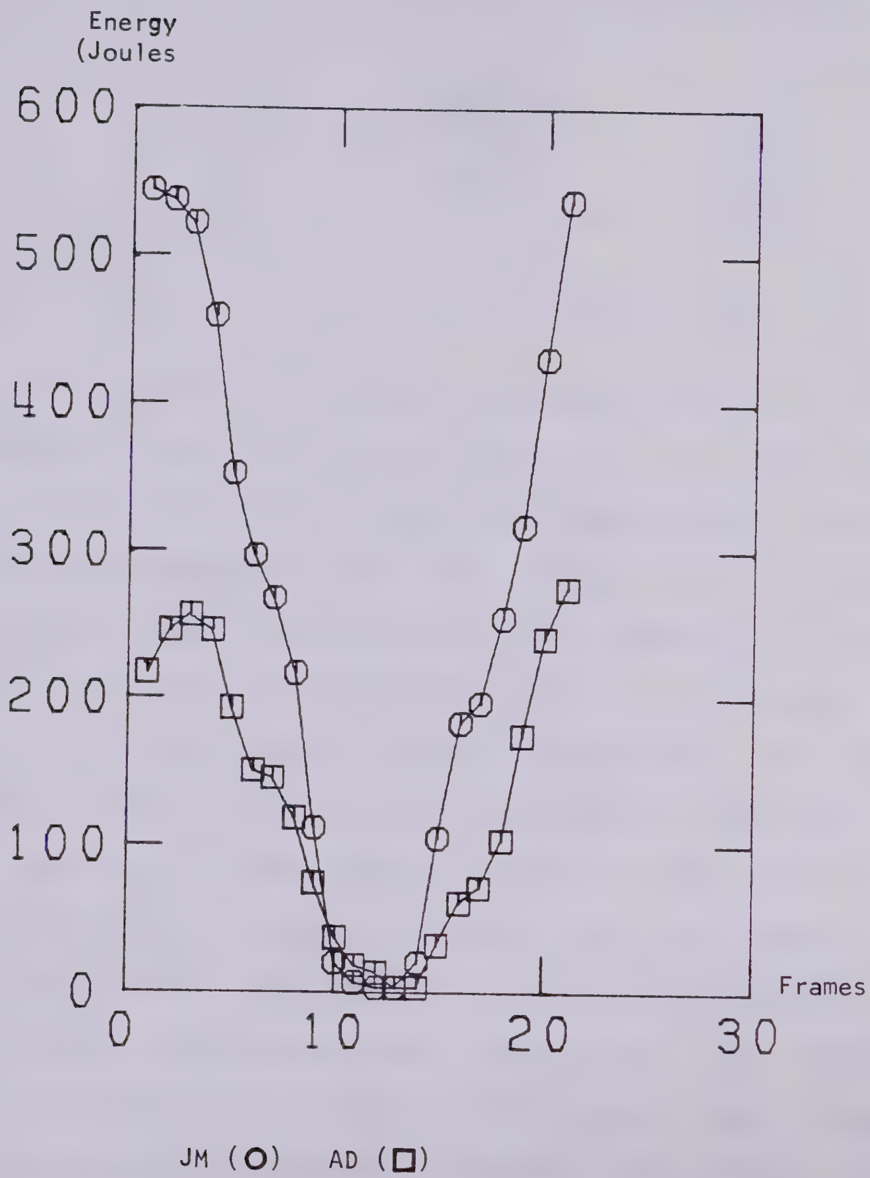

Figure 56. Frame By Frame Comparison of Potential Energy Between Subjects JM and AD.

the rail rather than circling upward.

Table 27. Mean Measures of Potential Energy in Joules for Groups I and IV for Significantly Different Phases

PHASE	GROUP I	GROUP IV	F*
1	499.08	357.08	5.08
5	21.97	9.67	8.12
6	166.94	92.53	11.10

* 1 F 12 = 4.75 at .05

The differences in potential energy naturally led to differences in kinetic energy (T) (Fig. 57). In all seven phases of skill execution Group I had significantly greater measures of kinetic energy (T) than Group IV. In most phases Group I had produced twice the amounts of kinetic energy (T) than Group IV. The differences in the moment of inertia (Ir) were most likely responsible for these differences. Even though Group IV had greater measures of angular velocity (Wr) and angular velocity (Wcm) than Group I, the differences in moment of inertia (Ir) and moment of inertia (Icm) were great enough to produce differences in the total kinetic energy measures (Table 28). The greater measures of moment of inertia (Ir) were most likely responsible for the differences occurring in Phases 1-6. The greater angular velocity (Wr) coupled with a large moment of inertia (Ir) at the final position during Phase 7 was probably the cause for the difference between the groups during that part of the straddle-out.

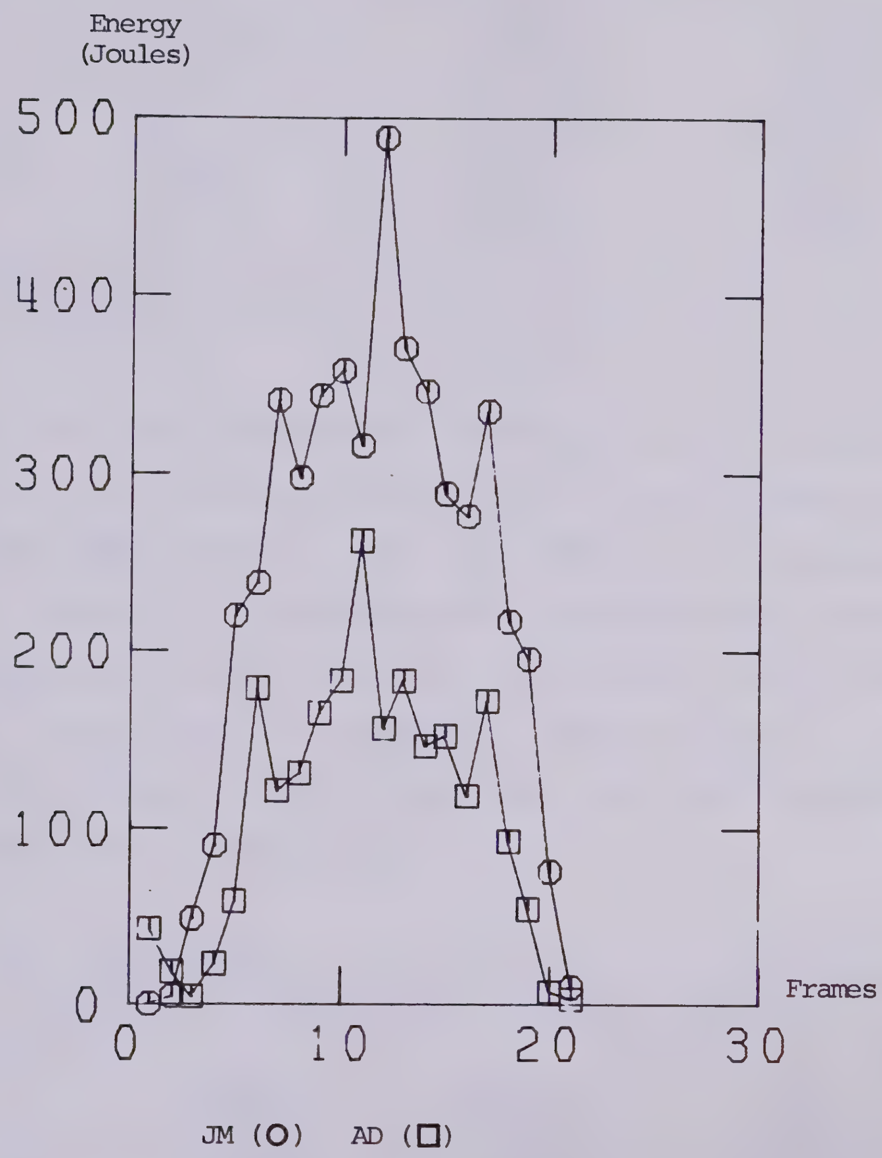

Figure 57. Frame By Frame Comparison of Kinetic Energy (T) Between JM and AD.

Table 28. Mean Measures of Total Kinetic Energy in Joules for All Phases of Skill Execution

PHASES	GROUP I	GROUP IV	F*
1	63.90	23.47	37.66
2	255.32	155.19	23.26
3	278.33	179.24	22.29
4	448.73	242.01	37.27
5	365.94	222.29	19.77
6	336.68	180.64	21.41
7	175.30	102.36	23.66

* 1 F 12 = 4.75 at .05

Due to the mathematical calculation of the kinetic energy (T), the effects of translational kinetic energy upon the total were greater than the effects of rotational kinetic energy. It follows then that comparisons between the groups showed that Group I trials had significantly greater values for translational kinetic energy in all phases than Group IV trials (Fig. 58). The only exception was during Phase 5 (Table 29).

Table 29. Mean Measures of Translational Kinetic Energy in Joules for Significantly Different Phases

PHASE	GROUP I	GROUP IV	F*
1	49.55	14.55	41.75
2	192.89	108.30	19.70
3	223.37	122.51	24.83
4	383.05	193.36	16.32
6	269.03	151.30	9.32
7	150.20	88.51	11.07

* 1 F 12 = 4.75 at .05

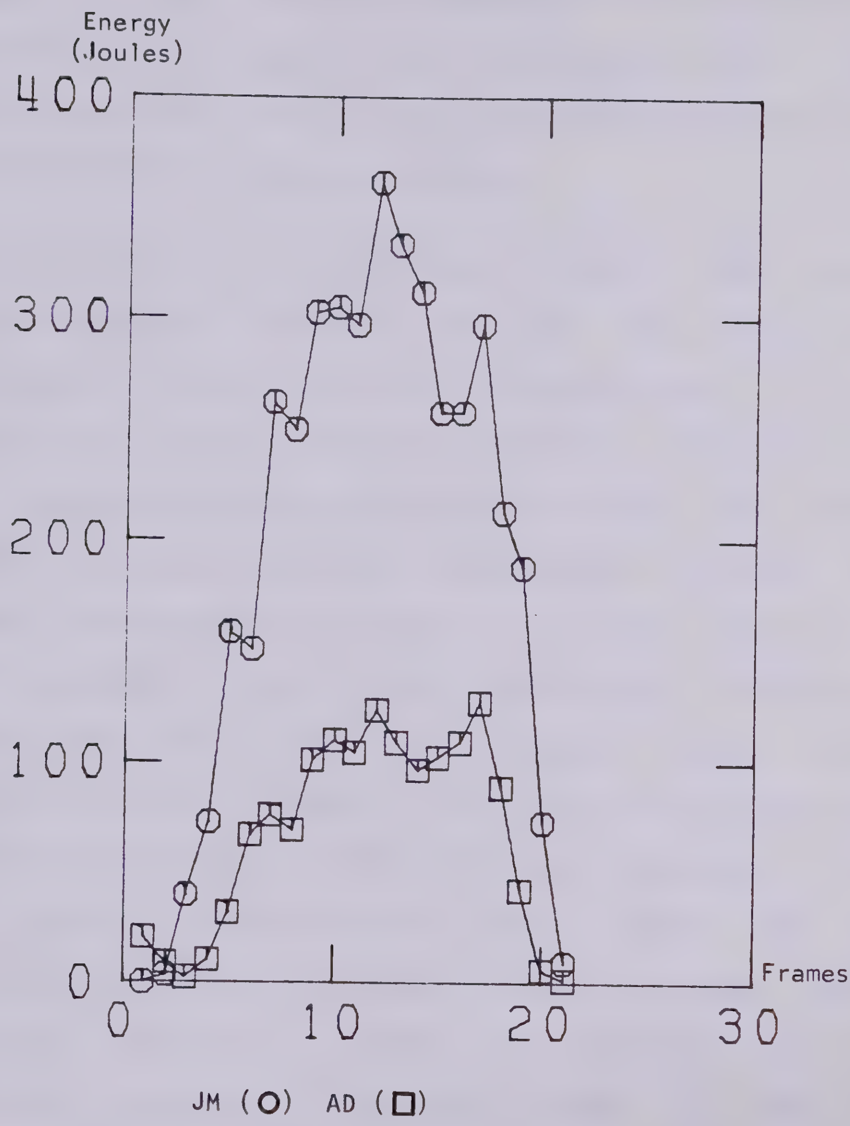

Figure 58. Frame By Frame Comparison of Translational Kinetic Energy Between Subjects JM and AD.

Only Phase 1, the straddle-in action was different for the variable of rotational kinetic energy ($_{1}F_{12} = 6.55$) (Fig. 59). Group I trials averaged 14.33J of rotational kinetic energy while Group IV trials averaged 8.91J. Body position differences during the straddle-in action would have caused this difference to occur.

Data presented show that Group I trials - the highest ranked performances according to the judges panel, had greater measures of kinetic variables than Group IV trials in almost all phases of skill execution. The analysis of variance revealed specific differences between the groups. The Pearson Product Moment Correlations revealed that significant relationships between the overall ranking and all the variables which showed differences between the groups were also significant. The Pearson Product Moment Correlations for all trials for variables which represented subject-specific and total skill data are presented in Table 30. For these variables, overall judges ranking was most highly correlated with the change in shoulder angle for the total Stalder (r=.664). Change in shoulder angle was significantly different between Groups I and IV. Differences in kinetic variables were shown to have been strongly affected by the amount of shoulder extension performed in the Stalder.

Trunk length was next most highly correlated with the overall ranking (r=-.583), yet the groups were not different

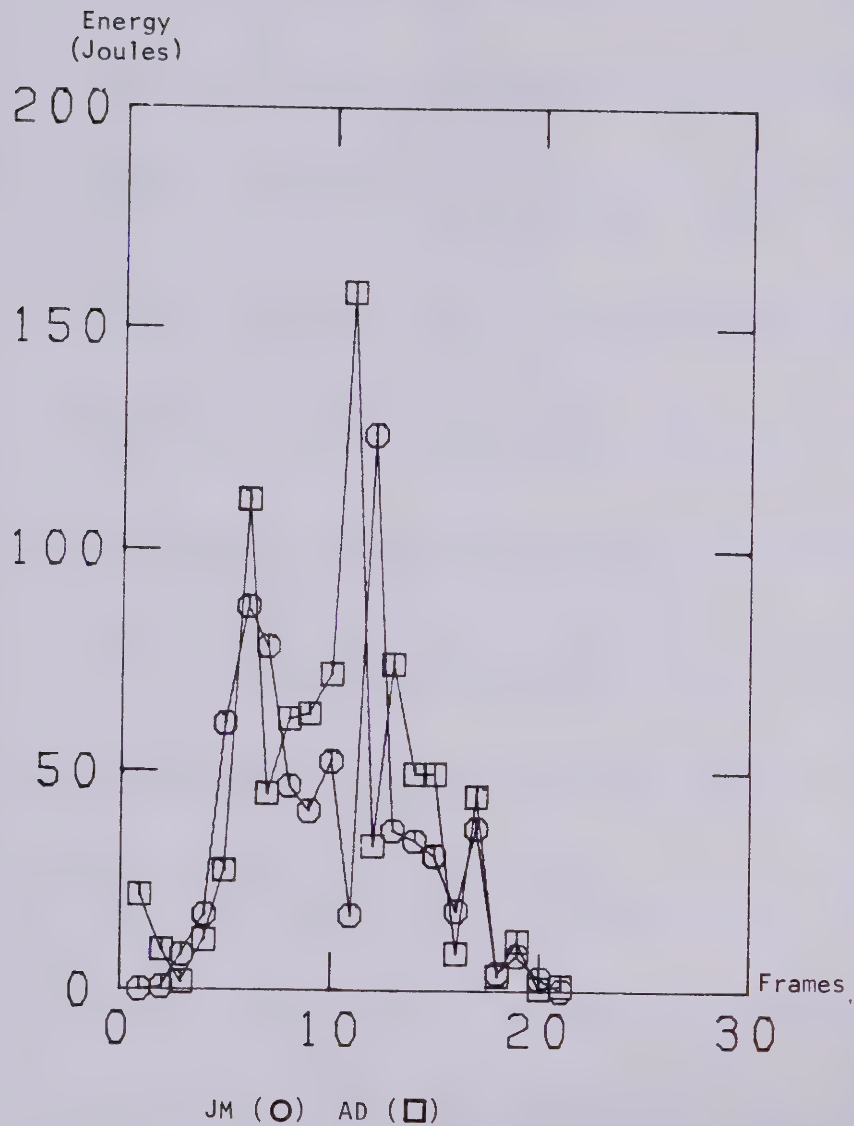

Figure 59. Frame By Frame Comparison of Rotational Kinetic Energy Between Subjects JM and AD.

Table 30. Pearson Product Moment Correlations Among Total Skill Variables for All Trials

VARIABLE	1	2	3	4	5	6	7	8	9	10	11	12
1. Rank	1.000	-.327	-.314	-.319	-.183	-.353	-.355	-.583**	-.165	-.277	.664**	-.295
2. Yrs. in Comp.	-.327	1.000	.758**	.618**	.563**	.318*	.569**	.729**	.502**	.630**	-.487**	.051
3. Age	-.314	.758**	1.000	.880**	.875**	.495**	.717**	.752**	.865**	.671**	-.221	-.145
4. Height	-.319	.618**	.880**	1.000	.963**	.778**	.901**	.786**	.899**	.615**	-.176	-.079
5. Mass	-.183	.563**	.875**	.963**	1.000	.717**	.829**	.730**	.926**	.536**	-.029	-.227
6. Up. Extremity Length	-.353	.318	.495**	.778**	.717**	1.000	.812**	.647**	.603**	.380*	-.134	.055
7. Low. Extremity Length	-.355	.569**	.717**	.901**	.829**	.812**	1.000	.666**	.794**	.575**	-.267	.031
8. Trunk Length	-.583**	.729**	.752**	.786**	.730**	.647**	.666**	1.000	.638**	.631**	-.449*	.143
9. Mean Grip Strength	-.165	.502**	.865**	.899**	.926**	.603**	.794**	.638**	1.000	.654**	-.086	-.192
10. Active Shoulder Flexibility	-.277	.630**	.671**	.615**	.536**	.380*	.575**	.631**	.654**	1.000	-.376*	.216
11. Shoulder Range of Motion	.664**	-.487**	-.221	-.176	-.029	-.134	-.267	-.449*	-.086	-.376*	1.000	-.613**
12. Passive Hip Flexibility	-.295	.051	-.145	-.079	-.227	.055	.031	143	-.192	.216	-.613**	1.000
13. Active Hip Flexibility	-.412*	.190	-.107	-.019	-.145	.057	.111	.291	-.128	.232	-.704**	.876**
14. Hip Range of Motion	-.260	.019	-.176	-.183	-.293	-.042	-.069	.091	-.245	.086	-.517**	.871**
15. Total Time	.309	.234	.130	.204	.273	.163	.282	.064	.227	-.102	.126	-.045
16. Time of Down Swing	.063	-.090	-.075	-.040	-.005	-.095	-.097	-.028	-.017	-.373	.125	-.066
17. Time of Up Swing	.383*	.241	.249	.312	.443*	.213	.346	.142	.333	.113	.252	-.314
18. Angular Velocity Total Skill	-.371	-.257	-.205	-.238	-.337	-.097	-.259	-.061	-.313	.128	-.215	.212
19. Angular Velocity Down Swing	-.382*	.105	-.010	-.080	-.159	.019	-.070	.152	-.142	.418*	-.393*	.201
20. Angular Velocity Up Swing	-.288	-.534**	-.372	-.312	-.413*	-.153	-.353	-.226	-.410*	-.307	-.005	.185
21. Yrs. Class I+	-.457*	.865**	.871**	.824**	.783**	.646**	.814**	.843**	.726**	.630**	-.409*	.019

*Significant at the .05 level of confidence (r= .375) **Significant at the .01 level of confidence (r= .479)

Table 30. continued

VARIABLE	13	14	15	16	17	18	19	20	21
1. Rank	-.412*	-.260	.309	.063	.383*	-.371	-.382*	-.288	-.457*
2. Yrs. in Competition	.190	.019	.234	-.090	.241	-.257	.105	-.534**	.865**
3. Age	-.107	-.176	.130	-.075	.249	-.205	-.010	-.372	-.871**
4. Height	-.019	-.183	.204	-.040	.312	-.238	-.080	-.312	.824**
5. Mass	-.145	-.293	.273	-.005	.443*	-.337	-.159	-.413*	.783**
6. Up. Extremity Length	.057	-.042	.163	-.095	.213	-.097	.019	-.153	.646**
7. Low. Extremity Length	.111	-.069	.282	-.097	.346	-.259	-.070	-.353	.814**
8. Trunk Length	.291	.091	.064	-.028	.142	-.061	.152	-.226	.843**
9. Mean Grip Strength	-.128	-.245	.227	-.017	.333	-.313	-.142	-.410*	.726**
10. Active Shoulder Flexibility	.232	.086	-.102	-.373	.113	.128	.418*	-.307	.630**
11. Shoulder Range of Motion	-.704**	-.517**	.126	.125	.252	-.215	-.393*	-.005	-.409*
12. Passive Hip Flexibility	.876**	.871**	-.045	-.066	-.314	.212	.201	.185	.019
13. Active Hip Flexibility	1.000	.691**	-.039	-.088	-.251	.169	.234	.091	.144
14. Hip Range of Motion	.691**	1.000	.155	.103	-.214	.013	.004	.097	-.014
15. Total Time	-.039	.155	1.000	.552**	.560**	-.912**	-.756**	-.598**	.231
16. Time of Down Swing	-.088	.103	.552**	1.000	-.017	-.587**	-.754**	.051	-.122
17. Time of Up Swing	-.251	-.214	.560**	-.017	1.000	-.565**	-.254	-.744**	.273
18. Angular Velocity Total Skill	.169	.013	-.912**	-.587**	-.565**	1.000	.838**	.660**	-.241
19. Angular Velocity Down Swing	.234	.004	-.756**	-.754**	-.254	.833**	1.000	.178	.047
20. Angular Velocity Up Swing	.091	.097	-.598**	.051	-.744**	.660**	.178	1.000	-.461*
21. Yrs. Class I+	.144	-.014	.231	-.122	.273	-.241	.047	-.461*	1.000

on this measure. Passive hip flexibility, in which Group I had greater flexion of the lower extremity to the trunk during the Stalder, was next most highly correlated with the overall ranking (r=-.412).

There was no difference between the groups on the total time of the up swing. The time for Phase 7 was different and this may have affected the correlation between the overall ranking and the time of the up swing (r=.383) indicating that faster circling in the second half of the skill aids in performance evaluation.

The relationship between the overall ranking and the number of years in competition (r=-.327) was not significant. However, the correlation between the overall ranking and the number of years as a Class I or higher competitive gymnast was significant (r=-.457). Although there were no differences between the groups on these variables, this seems to indicate that gymnasts who had achieved a high level of performance were likely to be more successful in Stalder performance regardless of their tenure as a competitor.

Significant correlations between the overall judges ranking and kinetic variables existed in all phases and variables where significant differences were revealed. All Pearson Product Moment Correlations between the overall ranking and all kinetic variables as well as values of angular velocity, mean shoulder angles and change in

shoulder angles for all phases of skill execution are listed in Table 31.

Table 31. Pearson Product Moment Correlations Between the Overall Judges Ranking and All Kinetic Variables for All Phases of Skill Execution

PHASE VARIABLE	1	2	3	4	5	6	7
Hr	-.638*	-.783**	-.801**	-.729**	-.721**	-.737**	-.864**
Wr	-.408	.613*	.644*	.463	.657*	.485	.150
Ir	-.343	-.788**	-.796**	-.681**	-.718**	-.697**	-.538
Hcm	-.700**	-.674*	-.575*	-.009	-.076	-.476	-.632*
Wcm	-.462	.415	.618*	.618*	.654*	.391	.146
Icm	-.356	-.587*	-.616*	-.651*	-.642*	-.556*	-.320
KE(R)	-.137	-.435	-.057	.440	.558*	-.405	-.362
KE(L)	-.591*	-.766**	-.860**	-.742**	-.336	-.759**	-.760**
KE(T)	-.532	-.771**	-.823**	-.864**	-.814**	-.866**	-.869**
PE	-.588*	-.390	-.480	.274	-.665*	-.707**	-.553
$\bar{x}$S θ	-.539	-.829**	-.818**	-.782**	-.779**	-.762**	-.672*
ΔS θ	.499	.195	.530	.141	.062	.048	.806**

r=.555 at .05 level of significance r=.680 at .01

DISCUSSION

The purpose of performing a Stalder is to add to the composition and difficulty level of a competitive uneven parallel bars routine. Evaluation of a specific element within a routine by the judges will included assessment of the technical execution of the element, the degree of internal and external amplitude displayed, the amount of swing or fluidity within the skill and between the preceding and following connecting moves, and the level of difficulty of the skill as listed in the current F.I.G. Code of Points. Difficulty of the Stalder is dependent on the final position attained by the gymnast. Stalders performed to a final

handstand are given 'C' difficulty while Stalders performed to a clear support or less than handstand position are given only 'B' difficulty (See Appendix D). This classification puts strong emphasis on the up swing and straddle-out action phases of the Stalder. The initial position of the Stalder does not influence the difficulty value placed on the element. Casting to less than a handstand at the beginning of the skill might cause amplitude deductions to be taken. The importance of the initial handstand lies with the effect that this position will have on kinematic and kinetic variables within the total skill. Casting to less than a handstand above the rail at the beginning of the Stalder puts the gymnast at a disadvantage in terms of developing maximum amounts of angular momentum (Hr) in the down swing. The measures of angular momentum (Hr) in the down swing directly affect the angular momentum (Hr) in the up swing and the ability to overcome the downward pull of gravity and allow the gymnast to swing to the final position. Therefore, even though the initial position of the skill is not evaluated in the difficulty rating of the skill, it definitely affects the ability of the gymnast to complete the Stalder in a handstand position.

The ranking of the trials by the judging panel was consistent with the difficulty rating even though the study was carried out prior to official use of the newest Code of Points which is the first Code to include the Stalder in its table of elements. All Group I (highest ranked) trials

completed the Stalder in a handstand position. Most Group IV (lowest ranked) trials ended in a clear support position or poorly executed handstand. It is the nature of uneven parallel bars work that all moves swing to completion rather than finish through press or muscling actions. The ranking of the trials was consistent on this point with Group I trials swinging to a final handstand with very little elbow flexion noted to aid in muscling actions. Group IV trials characteristically showed poor body positions, total lack of swing to the final position, and noticeable muscling from the arms to attain the final position. The difference reported in the amount of angular momentum (Hr) in the up swing affected the ability of the gymnasts to swing to the final position. Group I trials characteristically attained the final extended body position prior to the end of the up swing, but had sufficient angular momentum (Hr) to continue to swing to the handstand above the rail. Many Group IV trials had zero or negative values of angular momentum (Hr) at the end of the up swing. In order to complete the skill muscular work had to be performed to overcome gravity.

Differences in the starting positions for the two groups was different with Group I trials averaging 35 degrees more rotation in Phase 1 than Group IV trials. It was strongly stated in the literature and supported by the study that gymnasts who began the skill close to the handstand and with an extended body could generate greater swing and angular momentum (Hr) in the down swing. The

later in the down swing the straddle-in action took place, the greater yet the potential for successful performance. This was supported by the study as well. Although all subjects performed an early straddle-in technique (flexion at the hips occurred prior to extension at the shoulders), Group I performed a slower straddle-in action which was not completed until the hips were level with the high bar on the down swing or later. Group IV trials performed very rapid straddle-in actions and completed the action prior to the hips reaching the level of the rail on the down swing. This performance technique was supported by George (1969) who defined the straddle-in as the most critical portion of the skill. He reported that the straddle-in should be instantaneous. The study supports Osborne's (1978) statements that delaying the straddle-in action will enhance the generation of greater amounts of angular momentum by maintaining a longer radius of rotation in the down swing. Group I trials had significantly greater measures of moment of inertia (Ir) throughout the down swing than Group IV trials. It was supported by the data that this measure contributed to significant differences in the amount of angular momentum (Hr) created in the down swing as well. Because there were no differences between the groups on the variables of mass or segment lengths, differences in the moment of inertia (Ir) were caused primarily by less shoulder extension by Group I trials and to some extent to the slower straddle-in action of the legs which would aid in

maintaining a longer radius of rotation.

Most sources in the literature discussed the necessity of maintaining a narrow straddle of the legs in the straddle-in action to help increase the moment of inertia. All Group I trials maintained a very narrow straddle position with some trials not showing a separation of the feet at all until it was necessary to pass the legs by the hands in the rock back action. Group IV trials, in general, performed the straddle-in with a wide straddle. This was necessary in order to pass the feet over the rail before the rock back due to the closeness of the hips to the rail caused by the large amount of shoulder extension performed. This action would have reduced the radius of rotation and had an affect on the moment of inertia was well. The performance of the bottom swing was very different between the groups. The small amount of shoulder extension performed by Group I trials caused the hips to be further from the rail than the shoulders. This helped to maintain a large measure of moment of inertia and, therefore, angular momentum through the bottom swing. This position also put the gymnasts in a position to perform either flexion or extension of the upper extremity at the shoulders. Shoulder flexion did occur just prior to the straddle-out action. This caused a reduction in the moment of inertia and an increase in angular velocity to conserve angular momentum in the up swing. This action was coupled with the recoil of the rail. The increase in angular velocity plus the

additional force produced by the rail aided Group I trials in the completion of the skill.

In contrast, the Group IV trials showed continuous shoulder extension from the rock back through the bottom swing. This caused the gymnasts to completely invert and placed the hips closer to the rail than the shoulders. The literature supports holding a sufficiently decreased shoulder angle to prevent the body from unfolding as it passed below the bar. The opposite effect occurred in Group IV trials. As the gymnasts passed below the rail there was an increase in shoulder extension which caused the gymnasts to 'fold' further into an inverted dorsal hang. In this position, the only changes in shoulder position could come from shoulder flexion which would cause an increase in the radius of rotation. This would increase the moment of inertia and cause a decrease in the angular velocity.

The study supported Osborne's disagreement to George's statements relative to the actions of hip and shoulder articulations in the straddle-out. George reported that shoulder flexion and hip extension could occur simultaneously throughout the straddle-out. The Group I trials all performed the straddle-out by completing shoulder flexion prior to hip extension. Osborne's statement, supported by Plagenhoef, that simultaneous actions could inhibit each other was supported through the actions of the Group IV trials. Rapid hip extension at the start of the

straddle-out was performed. Little or no shoulder flexion was noted during this action. As hip extension was completed flexion at the elbows occurred in order to support the gymnast.

Rail deflections also appeared to affect the performance of the Stalders. Significant differences in rail deflection in the X direction during Phase 2 and in the Y direction during Phase 4 may have been responsible for increases in angular velocity and angular momentum at the start of the straddle-out when recoil of the rail occurred in the up swing. Increases in these variables occurred for all trials at this point. The additional force for Group I trials may or may not have made a difference in the outcome of the skill as Group I had large amounts of angular momentum in the up swing. The additional force produced by recoil of the rail may have made the difference in completing the Stalder for Group IV trials as they possessed small amounts of angular momentum in the up swing and any increase would have been advantageous to performance.

One difference between the highest and lowest ranked trials is the apparent ease in execution. The greater amounts of angular momentum and kinetic energy generated by Group I trials made the significant differences to the performances by Group IV trials. Differences in the amounts of these variables can be attributed primarily to the amount of shoulder extension performed throughout the skill.

CHAPTER V

SUMMARY AND CONCLUSION

The study was undertaken in an attempt to gain greater understanding of the biomechanical factors involved in the performance of the Stalder on the uneven parallel bars with respect to the general action of the skill as well as the critical factors which contribute to the successful performance of the Stalder. Fourteen gymnasts of Class I and Elite caliber were used as subjects. They were filmed, in the sagittal plane, performing two Stalders. The trials were filmed at 95 frames per second with a Photo-Sonics 1PL 16mm camera. A Hewlett-Packard 9825A mini-computer was used to receive and store digitized data points from a Bendix 9864A Digitizing Board. Computer programs written for the HP 9825A were used to reduce the data into specific kinematic and kinetic variables. A panel of expert judges viewed the film and ranked the trials from best to poorest as they compared to each other. The ranked trials were divided into four groups each containing seven trails. The data were then subjected to a complete biomechanical analysis. Statistical treatment of the data supplied Pearson Product Moment Correlations between the variables and a one way analysis of variance revealed significant differences between the groups on specific anthropometric, kinematic and kinetic variables.

CONCLUSIONS

On the basis of the data collected and analyzed in the study, the following conclusions seem supported:

1. Complete Stalder performance can be accomplished with a variety of techniques, however, certain styles are more effective in optimizing critical kinetic variables and influencing judges evaluation of the skill.

2. A high level of gymnastics expertise is more conducive to the success of Stalder performance than simply tenure as a competitor.

3. Stalder performance is initially enhanced by a starting position in or very near a handstand.

4. Good execution of the initial handstand increases control and maximizes the distance between the center of mass of the gymnast and the axis of rotation.

5. The straddle-in action of the legs should be delayed as long as possible in the down swing, and performed slowly, to maintain an optimum radius of rotation to maximize the moment of inertia (Ir).

6. The straddle of the legs in the straddle-in action should be kept as narrow as possible to minimize body position change and to maximize the moment of inertia (Ir).

7. Minimal extension of the upper extremity to the

trunk at the shoulders, from the initial handstand position, should occur to maximize the radius of rotation of the gymnast to the rail. This single measure has a direct affect on the amounts of moment of inertia (Ir), moment of inertia (Icm), angular momentum (Hr), angular momentum (Hcm), potential energy and kinetic energy (T).

8. Minimum amounts of shoulder extension place the gymnast in body positions which are conducive to subtle changes in body position which favor increases in shoulder extension rather than shoulder flexion.

9. Hip flexion should be maximized, however, range of motion in hip action is less important to successful Stalder performance than is shoulder range of motion.

10. Maximized moments of inertia throughout the down swing contribute to greater rail deflections by contributing to greater horizontal and vertical velocities of the center of mass, thus, increasing the loads against the rail.

11. Body positions throughout the entire Stalder should be such that the hips are always further from the rail than are the shoulders.

12. Straddle-out actions should be timed to begin with the recoil of the rail on the upswing.

13. A wide straddling of the legs, in the frontal plane, during the straddle-out will not affect the radius of

rotation as much as straddle-out with the action of the legs in the sagittal plane. This action is desirable in that it will not affect changes in moments of inertia or angular momentum.

14. Extension of the legs at the hips should occur throughout the straddle-out action. The final action made to attain the final handstand should be hip extension. Slower extension of the legs have less effect on center of mass changes in will not inhibit shoulder flexion.

15. Shoulder flexion followed by hip extension into the final handstand position enhances swing and ease in attaining the final position.

16. Good Stalder performances produce forces of 1.99 to 3.30 times the body weight of the gymnast as she passes below the rail at the bottom of the swing.

17. Recoil of the deflected rail in Stalders with optimum angular momentum (Hr) and kinetic energy (T) measures may produce sufficient force to increase the angular velocity (Wr), thus, increase the angular momentum (Hr) and kinetic energy (T) in the upswing.

IMPLEMENTATIONS

The following statements, based on the results of data analysis and conclusions of the study, are included for the purpose of implementations of the results of the study:

1. Gymnasts should be highly skilled in basic uneven parallel bars actions before attempting handstand to handstand Stalder circles.

2. Coaches, through review of high speed film and familiarity with research findings, should be completely familiar with optimal performance techniques of the Stalder.

3. Coaches should make every effort to get their gymnasts to minimize shoulder extension throughout the Stalder. This one factor directly affects the greatest number of critical variables to successful performance.

4. Judges should focus attention on the upper body action to fairly evaluate Stalder performance with respect to biomechanical considerations.

RECOMMENDATIONS

From the results of the study it is recommended that:

1. Further study be undertaken:

a. with additional instrumentation to obtain precise knowledge of the interaction between the gymnast and the rail.

b. to measure shoulder girdle strength relative to maintaining an open inverted dorsal hang position in the performance of a Stalder.

c. of Stalder performance in a competitive situation.

2. Studies be conducted with a greater number of subjects, both skilled and unskilled in Stalder performance, to determine more specifically the factor which limit execution of the Stalder.

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APPENDIX A

Filming Data

Measurements, Equipment, and Camera Settings

	SESSION I	SESSION II
Date	May 13, 1980	May 15, 1980
Height of Rail	229cm	225cm
Height of Lens	229cm	225cm
Camera to Subject Distance	13m	13m
Reference Measures	28cm	28cm
Film	Kodak Ektachrome 7250 EF Tungsten	Kodak Ektachrome 7250 EF Tungsten
ASA	400	400
Camera Frame Rate	100 f/s	100 f/s
Timing Light Generator Setting	10Hz	10Hz
Light Meter Reading	9.5	8.25
Shutter Angle	120°	160°
Exposure Time	1/300 sec.	1/220 sec.
Aperture	f2.2	f2.2
Development	Normal	Push 1x to ASA 800

APPENDIX B

Judges Data

NAME	CGF/FIG RATING	YEARS OF JUDGING EXPERIENCE
Kathy Krystofiak	National 1	6
Doreen McCharles	National 2	10
Betty Nadurak	National 1	7
Dorothy Ostrowercha	Regional 2	3
Joan Payne	Provincial 2*	10
Jill Prendergast**	International	10
Susan Rouse	Provincial 1	7
Yvonne Van Sost	Provincial 1	6
Judy Weppler	National 1	11

* National Eligible 1980-81
** A.G.F. Women's Judging Chairperson

APPENDIX C

Correlation Matrix of Judges Rankings

PEARSON PRODUCT MOMENT CORRELATIONS FOR ALL JUDGES AND OVERALL RANKING

	OVERALL RANK	1	2	3	4	5	6	7	8	9
OVERALL RANK	1.00	.313	.307	.397	.142	.372	.166	.142	.144	.136
1	.313	1.00	.339	.443	.495	-.093	.426	-.224	.068	.485
2	.307	.339	1.00	.024	.243	.299	.085	.169	.011	.120
3	.397	.443	.024	1.00	.015	.158	.021	.089	.080	.217
4	.142	.495	.243	.015	1.00	-.131	.165	-.130	-.154	.424
5	.372	.093	.299	.158	-.131	1.00	.022	.248	.429	.289
6	.166	.426	.085	.021	.165	.022	1.00	-.015	.067	.322
7	.142	-.244	.169	.089	-.130	.248	-.015	1.00	.118	-.183
8	.144	.068	-.011	-.080	-.154	.429	-.067	.118	1.00	.417
9	.136	.485	.120	-.217	-.424	.289	.322	-.183	-.417	1.00

APPENDIX D

F.I.G. Point Breakdown

THE EVALUATION OF OPTIONAL EXERCISES

The optional exercise on the apparatus - uneven bars, balance beam, and floor will be evaluated from 9.5 points.
For special performance a bonus of 0.50 points total is possible so that a maximum of 10.00 points can be reached.

REQUIREMENTS OF THE EXERCISE

The evaluation of the optional exercises follows based upon these taxation factors (formula):

Value Parts (difficulties)	3.00 points
Bonus Points	0.50 points
Combinations (construction of the exercise)	2.50 points
Execution and Virtuosity	4.00 points
	10.00 points maximum

Value Parts (Difficulties)

Competition 1B	Competition II	Competition III
6 A 0.20 = 1.20 pt.	4 A 0.20 = 0.80 pt.	2 A 0.20 = 0.40 pt.
3 B 0.40 = 1.20 pt.	4 B 0.40 = 1.60 pt.	2 B 0.40 = 0.80 pt.
1 C 0.60 = 0.60 pt.	1 C 0.60 = 0.60 pt	3 C 0.60 = 1.80 pt.
Value Parts = 3.00 pt.	= 3.00 pt.	3.00 points

Bonus Points

Originality (maximum)	0.20 points
Risk (C^r) (maximum)	0.20 points
Additional C or more than one C^r (maximum)	0.10 points
	0.50 points

Combination

Progressive distribution of elements. Mount and dismount corresponding to the value of the exercise.	0.50 points
Composition of the exercise from various elements and connections.	1.00 points
Space and direction	0.60 points
Tempo and Rhythm	0.40 points
	2.50 points

Execution and Virtuosity

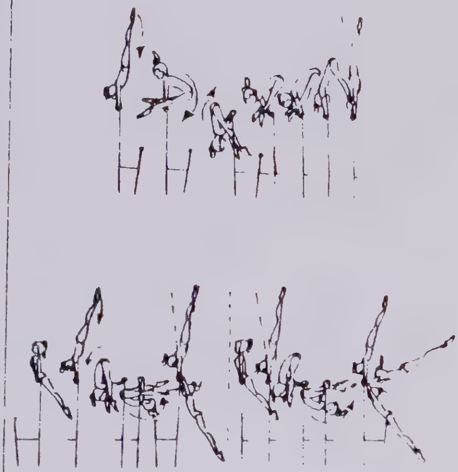
Virtuosity	0.20 points
Technique/Amplitude/Posture	3.80 points
	4.00 points

10.00 points

APPENDIX E

F.I.G. Stalder Difficulty Classification

rcles

A	B	C
	2 29 Stalder backward or forward to clear support or hang 	2 30 Stalder backward or forward to handstand 

(F.I.G. Code of Points, 1979)

APPENDIX F

Subject Data

NAME	AGE IN YEARS	YEARS IN COMPETITION	LEVEL OF COMPETITION	HOME COUNTRY
Juliann Brumbaugh	11.5	4	Class I*	U.S.A.
Angela Daquista	11.5	2	Class I*	U.S.A.
Jo Faber	14.5	3	Class I	U.S.A.
Nanci Goldsmith	13.5	4	Class I	U.S.A.
Carrie Hoit	11.0	1.5	Class I*	U.S.A.
Karen Kelsall	17.5	7	Elite III	Canada
Jean Lee	16.0	4.5	Class I	U.S.A.
Julianne McNamara	14.5	3	Elite	U.S.A.
Yolande Mavity	11.5	2	Class I*	U.S.A.
Tiffany Quincy	11.0	3	Class I	U.S.A.
Tracee Talavera	13.5	5	Elite	U.S.A.
Jayne Weinstein	16.5	5	Elite	U.S.A.
Julie Weinstein	14.0	5	Class I	U.S.A.
Dawna Wilson	12.0	3	Class I	U.S.A.

* Class I Level obtained one week prior to filming sessions.

APPENDIX G

Raw Data Variables for Total Skill for All Subjects

SUBJECT /TRIAL	RANK	AGE YRS.	HEIGHT CM	MASS KG	UP.EX. LENGTH CM	LW.EX. LENGTH CM	TRUNK LENGTH CM
JYW2	1	16.5	154.94	42.64	41.82	66.00	50.91
TT2	2	13.5	148.59	38.56	50.62	68.48	52.25
JYW1	3	16.5	154.94	42.64	41.82	66.00	50.91
JM2	4	14.5	147.32	38.56	46.50	63.21	49.53
JM1	5	14.5	147.32	38.56	46.50	63.21	49.53
DW2	6	12.0	135.89	32.20	41.73	58.84	48.20
TT1	7	13.5	148.59	38.56	50.62	68.48	52.25
DW1	8	12.0	135.89	32.20	41.73	58.84	48.20
NG2	9	13.5	138.43	32.66	40.03	61.42	45.99
KK2	10	17.5	156.21	44.45	43.24	65.23	57.37
NG1	11	13.5	138.43	32.66	40.03	61.42	45.99
KK1	12	17.5	156.21	44.45	43.24	65.23	57.37
CH2	13	11.0	124.46	26.76	37.72	56.85	41.77
TQ2	14	11.0	127.00	28.92	38.27	58.07	46.56
JLW2	15	14.0	147.32	38.10	43.28	66.10	45.63
YM1	16	11.5	141.61	33.57	44.48	59.65	47.77
TQ1	17	11.0	127.00	28.92	38.27	58.07	46.56
JF1	18	14.5	139.70	38.67	42.11	58.30	45.74
YM2	19	11.5	141.61	33.57	44.48	59.65	47.77
CH1	20	11.0	124.46	26.76	37.72	56.85	41.77
JLW1	21	14.0	147.32	38.10	43.28	66.10	45.63
JL1	22	16.0	163.83	54.20	47.48	69.26	49.91
JF2	23	14.5	139.70	38.67	42.11	58.30	45.74
JB1	24	11.5	121.92	24.95	35.95	52.20	42.13
AD1	25	11.5	129.54	26.76	39.68	60.19	40.02
JB2	26	11.5	121.92	24.95	35.95	52.20	42.13
AD2	27	11.5	129.54	26.76	39.68	60.19	40.02
JL2	28	16.0	163.83	54.20	47.48	69.26	49.91

SUBJECT /TRIAL	YRS. IN COMP	SHLDR FLEX RADS	SHLDR ROM RADS	A. HIP FLEX RADS	P. HIP FLEX RADS	HIP ROM RADS	YRS. + CLASS I
JYW2	5	3.86	1.10	3.24	3.27	3.02	3
TT2	5	3.62	1.17	3.45	3.41	3.34	4
JYW1	5	3.86	1.15	3.36	3.27	3.29	3
JM2	3	3.39	1.47	3.03	2.91	3.03	2.5
JM1	3	3.39	1.70	3.06	2.91	3.06	2.5
DW2	3	3.17	2.10	3.10	3.03	3.10	1
TT1	5	3.62	1.15	3.45	3.41	3.40	4
DW1	3	3.17	1.62	3.04	3.03	3.04	1
NG2	4	3.26	1.63	3.14	3.07	3.14	2
KK2	7	3.75	1.46	3.35	3.31	3.32	5
NG1	4	3.26	1.47	3.13	3.07	2.95	2
KK1	7	3.75	1.24	3.32	3.31	3.33	5
CH2	1.5	3.15	1.43	3.52	3.39	3.52	.1
TQ2	3	3.43	1.92	3.10	3.26	3.10	1
JLW2	5	3.37	1.66	3.11	3.23	2.82	3
YM1	2	3.44	1.80	3.48	3.39	3.44	.1
TQ1	3	3.43	1.51	3.07	3.26	2.95	1
JF1	3	3.42	2.33	2.99	2.88	2.78	2
YM2	2	3.44	1.69	3.43	3.39	3.06	.1
CH1	1.5	3.15	1.54	3.45	3.39	3.48	.1
JLW1	5	3.37	1.58	3.25	3.23	3.25	3
JL1	4	3.47	2.15	2.90	3.14	1.49	3
JF2	3	3.42	2.20	3.03	2.88	3.01	2
JB1	4	3.33	1.65	3.12	2.96	3.12	.1
AD1	2	3.49	2.08	3.12	2.89	3.06	.1
JB2	4	3.33	1.70	3.12	2.96	3.08	.1
AD2	2	3.49	2.28	3.17	2.89	3.17	.1
JL2	4	3.47	2.19	2.89	2.79	2.71	3

SUBJECT /TRIAL	$\bar{x}$ GRIP STRNTH KG	TOTAL TIME SEC	DW SW TIME SEC	UP SW TIME SEC	TOTAL A.VEL R/S	DW SW A.VEL R/S	UP SW A.VEL R/S
JYW2	20.50	2.09	1.10	1.00	2.91	2.54	3.30
TT2	13.34	2.33	1.16	1.18	2.58	2.37	2.81
JYW1	20.25	2.31	1.28	1.03	2.71	2.21	3.33
JM2	17.63	2.45	1.63	.82	2.50	1.81	3.89
JM1	17.63	2.24	1.34	.89	2.69	2.09	3.24
DW2	7.84	2.59	1.69	.90	2.43	1.73	3.74
TT1	13.34	2.78	1.16	1.23	2.67	2.63	3.01
DW1	7.84	2.38	1.44	1.39	2.61	2.04	3.50
NG2	9.34	2.33	1.32	1.01	2.67	2.06	3.47
KK2	18.67	2.57	1.44	1.13	2.37	1.96	2.91
NG1	9.34	2.19	1.19	1.01	2.84	2.26	3.53
KK1	18.67	2.73	1.46	1.27	2.23	1.93	2.59
CH2	9.33	2.55	1.51	1.04	2.44	1.81	3.36
TQ2	11.00	2.64	1.40	1.24	2.37	1.99	2.80
JLW2	15.05	2.64	1.56	1.08	2.28	1.79	3.00
YM1	11.13	2.26	1.38	.88	2.75	2.03	3.90
TQ1	11.00	2.17	1.14	1.03	2.75	2.31	3.26
JF1	14.08	2.25	1.13	1.11	2.71	2.12	3.32
YM2	11.13	2.23	1.26	.97	2.84	2.22	3.66
CH1	9.33	2.76	1.66	1.10	2.32	1.64	3.35
JLW1	15.05	3.02	1.24	1.19	1.97	1.51	2.69
JL1	23.50	3.14	1.49	1.65	1.92	1.64	2.19
JF2	14.08	2.28	1.07	1.19	2.68	2.21	3.11
JB1	7.00	2.71	1.65	1.06	2.27	2.00	2.70
AD1	10.34	2.24	1.03	1.21	2.65	2.23	3.03
JB2	7.00	2.36	1.25	1.11	2.61	2.16	3.11
AD2	10.34	2.62	1.51	1.11	2.53	1.80	3.55
JL2	23.50	2.71	1.56	1.44	2.10	1.58	2.82

APPENDIX H

Raw Data Variables for All Phases for All Subjects

TIME IN SECONDS

SUBJECT	PHASE 1	2	3	4	5	6	7
JYW2	.81	.02	.27	.02	.27	.02	.74
TT2	.85	.02	.30	.02	.28	.02	.89
JYW1	.99	.02	.29	.02	.27	.02	.77
JM2	1.37	.02	.26	.02	.25	.02	.57
JM1	1.07	.02	.27	.02	.24	.02	.65
DW2	1.43	.02	.25	.02	.23	.02	.68
TT1	.86	.02	.29	.02	.27	.02	.85
DW1	1.18	.02	.25	.02	.24	.02	.71
NG2	1.08	.02	.23	.02	.24	.02	.78
KK2	1.17	.02	.27	.02	.29	.02	.84
NG1	.96	.02	.22	.02	.25	.02	.77
KK1	1.18	.02	.28	.02	.29	.02	.98
CH2	1.28	.02	.23	.02	.24	.02	.80
TQ2	1.12	.02	.27	.02	.26	.02	.98
JLW2	1.25	.02	.30	.02	.25	.02	.84
YM1	1.12	.02	.26	.02	.24	.02	.64
TQ1	.88	.02	.26	.02	.26	.02	.77
JF1	.88	.02	.25	.02	.25	.02	.86
YM2	1.00	.02	.26	.02	.24	.02	.72
CH1	1.42	.02	.24	.02	.23	.02	.87
JLW1	1.52	.02	.30	.02	.26	.02	.93
JL1	1.18	.02	.32	.02	.25	.02	1.40
JF2	.84	.02	.25	.02	.25	.02	.93
JB1	1.41	.02	.24	.02	.23	.02	.83
AD1	.79	.02	.24	.02	.25	.02	.96
JB2	1.00	.02	.25	.02	.22	.02	.89
AD2	1.28	.02	.23	.02	.25	.02	.86
JL2	1.24	.02	.33	.02	.26	.02	.88

DISPLACEMENT IN RADIANS

SUBJECT	PHASE 1	2	3	4	5	6	7
JYW2	1.26	.08	1.47	.12	1.54	.14	1.81
TT2	1.14	.08	1.55	.12	1.55	.10	1.78
JYW1	1.28	.07	1.48	.15	1.58	.13	1.92
JM2	1.35	.10	1.56	.12	1.53	.12	1.68
JM1	1.23	.09	1.53	.13	1.54	.12	1.73
DW1	1.36	.10	1.49	.14	1.49	.14	1.95
TT1	1.19	.10	1.53	.14	1.53	.10	1.79
DW1	1.31	.13	1.54	.15	1.61	.11	1.76
NG2	1.10	.12	1.55	.14	1.60	.12	1.98
KK2	1.28	.09	1.51	.11	1.63	.10	1.68
NG1	1.10	.13	1.52	.13	1.65	.12	1.95
KK1	1.21	.10	1.56	.13	1.65	.10	1.68
CH2	1.20	.11	1.50	.14	1.65	.12	1.87
TQ2	1.09	.11	1.65	.13	1.67	.13	1.84
JLW2	1.11	.10	1.61	.15	1.58	.10	1.73
YM1	1.23	.10	1.50	.14	1.58	.13	1.89
TQ1	1.01	.10	1.59	.14	1.75	.07	1.62
JF1	.79	.10	1.55	.15	1.84	.16	1.92
YM2	1.24	.12	1.51	.14	1.55	.16	2.03
CH1	1.11	.13	1.56	.14	1.66	.12	2.06
JLW1	1.08	.10	1.62	.14	1.66	.11	1.58
JL1	.72	.09	1.69	.11	1.60	.09	2.03
JF2	.87	.09	1.49	.13	1.76	.17	1.99
JB1	1.20	.16	2.05	.14	1.42	.12	1.49
AD1	.71	.10	1.54	.11	1.68	.17	2.01
JB2	1.06	.11	1.61	.14	1.63	.15	1.86
AD2	1.16	.11	1.51	.15	1.55	.13	2.40
JL2	.71	.10	1.74	.13	1.66	.14	1.58

ANGULAR VELOCITY IN RADIANS/SECOND

SUBJECT	PHASE 1	2	3	4	5	6	7
JYW2	1.55	3.72	5.37	5.85	5.62	6.63	2.47
TT2	1.34	3.77	5.09	5.76	5.47	4.87	2.00
JYW1	1.30	3.39	5.22	7.05	5.78	6.08	2.50
JM2	.99	4.82	5.94	5.49	6.07	5.71	2.96
JM1	1.45	4.10	5.61	6.14	6.37	5.86	2.66
DW2	.96	4.63	5.91	6.73	6.46	6.59	2.85
TT1	1.39	4.63	5.21	6.25	5.60	4.61	2.10
DW1	1.11	6.31	6.11	7.16	6.68	5.38	2.47
NG2	1.02	5.60	6.72	6.61	6.61	5.67	2.55
KK2	1.10	4.42	5.54	5.22	5.53	4.98	2.01
NG1	1.45	6.09	6.90	6.03	6.54	5.83	2.54
KK1	1.03	4.77	5.52	6.06	5.60	4.78	1.72
CH2	.94	5.14	6.51	6.47	6.83	5.56	2.34
TQ2	.97	5.00	6.04	6.15	6.35	6.37	1.89
JLW2	.89	4.86	5.28	7.03	6.28	4.99	2.06
YM1	1.10	4.86	5.72	6.48	6.56	5.98	2.96
TQ1	1.14	5.00	6.04	6.67	6.67	3.16	2.11
JF1	.90	4.64	6.14	7.13	7.30	7.41	2.23
YM2	1.25	5.89	5.73	6.81	6.44	7.51	2.80
CH1	.79	6.17	6.44	6.80	7.19	5.84	2.36
JLW1	.71	4.56	5.33	6.67	6.34	5.45	1.69
JL1	.61	4.21	5.37	5.03	6.36	4.30	1.45
JF2	1.04	4.19	5.93	6.02	6.97	7.86	2.13
JB1	.85	7.55	8.50	6.85	6.17	5.92	1.79
AD1	.91	4.99	6.39	5.25	6.67	8.08	2.10
JB2	1.06	5.12	6.39	6.70	7.39	7.09	2.08
AD2	.91	5.43	6.52	6.93	6.17	6.37	2.79
JL2	.57	4.71	5.33	6.03	6.31	6.53	1.79

APPENDIX I

Raw Data Variables for Subject JM

ANGULAR KINEMATICS: CENTER OF MASS — JULIANNE McNAMARA TRIAL 2

FRAME #	CM COORDINATES X	CM COORDINATES Y	LINEAR DISTANCE CM TO HB (cm)	TIME sec	DISPLACEMENT rad	VELOCITY rad/sec
1	21.1544	47.9695	79.5790			
2	20.5547	48.0340	79.7637	0.2100	0.0282	0.1342
3	15.5204	46.5152	76.2248	0.7350	0.2483	0.3378
4	14.0274	45.7034	74.8409	0.0630	0.0820	1.3016
5	8.5680	38.1642	61.3707	0.2310	0.4772	2.0657
6	5.3767	30.5989	57.6841	0.1260	0.5172	4.1048
7	5.2881	29.9647	57.4514	0.0105	0.0413	3.9362
8	4.9975	29.0792	57.9068	0.0105	0.0598	5.6968
9	4.6590	23.4971	59.6556	0.0630	0.3558	5.6483
10	10.9378	12.4042	63.7450	0.1260	0.7892	6.2631
11	15.6879	9.9209	64.8774	0.0525	0.3119	5.9416
12	16.6155	9.7404	64.6993	0.0105	0.0544	5.1798
13	17.6557	9.5747	64.5929	0.0105	0.0608	5.7924
14	22.2131	9.6642	63.8804	0.0420	0.2655	6.3207
15	28.4130	11.9174	62.8193	0.0630	0.3909	6.2046
16	35.3641	21.8140	59.0181	0.1260	0.7568	6.0064
17	35.6700	22.6045	59.2826	0.0105	0.0533	5.0780
18	35.8468	23.6460	59.0558	0.0105	0.0666	6.3384
19	34.8342	31.8625	57.5494	0.0945	0.5359	5.6711
20	34.2273	33.4387	57.7435	0.0210	0.1094	5.2086
21	26.2600	47.0365	79.2026	0.3255	0.8341	2.5624
22	24.7041	48.0785	81.5836	0.1050	0.0818	0.7790

****

ANGULAR KINEMATICS: CENTER OF MASS JULIANNE McNAMARA TRIAL 2

****

BETWEEN FRAMES	TIME sec	DISPLACEMENT rad	VELOCITY rad/sec
HIGHEST CAST TO HIPS AT HB LEVEL			
1 TO 6	1.3650	1.3528	0.9911
HIPS AT HB LEVEL			
6 TO 8	0.0210	0.1011	4.8165
HIPS AT HB LEVEL TO HIPS BELOW HB			
6 TO 11	0.2625	1.5581	5.9355
HIPS BELOW HB			
11 TO 13	0.0210	0.1152	5.4861
HIPS BELOW HB TO HIPS AT HB LEVEL			
11 TO 16	0.2520	1.5284	6.0650
HIPS AT HB LEVEL			
16 TO 18	0.0210	0.1199	5.7082
HIPS AT LEVEL OF HB TO FINISH			
16 TO 22	0.5670	1.6810	2.9648

************** DATA FOR ANGLE/ANGLE DIAGRAM **************

JULIANNE McNAMARA TRIAL 2

****

FRAME #	SHOULDER ANGLE (IN RADIANS)	HIP ANGLE (IN RADIANS)
1	3.1299 (179.3325)	0.3639 (20.8489)
2	3.0886 (176.9622)	0.3434 (19.6760)
3	2.9113 (166.8031)	0.8200 (46.9815)
4	2.9082 (166.6303)	1.2387 (70.9734)
5	2.4991 (143.1889)	2.0885 (119.6640)
6	2.0900 (119.7489)	2.5610 (146.7333)
7	1.9931 (114.1977)	2.5754 (147.5593)
8	1.9594 (112.2683)	2.5846 (148.0876)
9	1.8011 (103.1986)	2.6790 (153.4967)
10	1.9171 (109.8409)	2.9397 (168.4348)
11	1.8367 (105.2339)	3.0000 (171.8878)
12	1.9516 (111.8180)	2.9937 (171.5274)
13	1.8260 (104.6209)	3.0344 (173.8601)
14	1.9205 (110.0365)	2.9835 (170.9444)
15	1.7230 (98.7233)	3.0109 (172.5144)
16	1.7770 (101.8178)	2.6914 (154.2081)
17	1.7520 (100.3829)	2.6236 (150.3234)
18	1.7498 (100.2581)	2.6265 (150.4904)
19	2.0248 (116.0118)	2.2033 (126.2414)
20	1.9934 (114.2134)	2.0280 (116.1941)
21	2.7308 (156.4643)	0.2270 (13.0089)
22	2.9630 (169.7691)	0.2942 (16.8537)

JULIANNE McNAMARA TRIAL 2 38.6 Kg

		LOC	Hr	Wr	Ir	Hcm	Wcm	Icm
1	0.00							
2	0.21	0.53	4.49	0.17	27.15	1.44	0.35	4.14
3	0.95	0.95	11.39	0.45	25.13	4.03	1.19	3.38
4	1.01	4.16	41.94	1.71	24.49	15.22	4.00	3.80
5	1.24	3.50	46.28	2.57	18.04	8.91	4.57	1.95
6	1.37	14.16	73.95	5.44	13.58	23.09	18.45	1.25
7	1.38	16.70	76.09	5.53	13.76	27.81	20.97	1.33
8	1.39	15.96	98.29	7.12	13.81	27.44	20.70	1.33
9	1.45	12.43	93.14	6.76	13.78	21.62	18.42	1.17
10	1.58	11.73	95.68	7.24	13.21	18.65	19.44	0.96
11	1.63	13.29	112.07	6.82	16.43	20.99	18.13	1.16
12	1.64	-0.22	88.99	5.21	17.08	5.54	4.62	1.20
13	1.65	20.13	124.06	7.30	17.00	31.50	26.73	1.18
14	1.69	11.03	114.48	6.94	16.49	17.91	16.11	1.11
15	1.75	10.72	108.09	6.89	15.68	17.39	16.50	1.05
16	1.88	9.97	87.66	6.68	13.13	14.75	15.62	0.94
17	1.89	4.55	79.21	5.49	14.42	11.02	9.85	1.12
18	1.90	9.69	97.24	6.73	14.45	14.03	12.31	1.14
19	2.00	2.13	68.83	5.24	13.13	3.15	2.67	1.18
20	2.02	-2.51	60.46	4.39	13.78	-4.14	-2.94	1.41
21	2.34	2.43	39.25	2.37	16.54	1.18	0.53	2.21
		0.14	18.66	0.68	27.64	0.09	0.02	4.26

JULIANNE McNAMARA TRIAL 2 39Kg

ENERGY IN JOULE

	HN	T	RUA	RLA	RH	LUA	LLA	LH	RT	RLL	RF	LT	LLL	LF				
1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	R=	0.1		
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.1	0.0	T=	0.3	SUM=	0.4
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.2	0.1	0.0	R=	0.6		
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.9	0.6	0.3	0.9	0.6	T=	3.8	SUM=	4.4
3	0.1	1.7	0.0	0.0	0.0	0.0	0.0	0.0	2.5	0.6	0.1	2.5	0.6	0.1	R=	8.1		
	0.1	6.2	0.2	0.1	0.0	0.2	0.1	0.0	3.1	8.2	5.4	3.1	8.2	5.4	T=	40.2	SUM=	48.2
4	0.2	10.7	0.0	0.0	0.0	0.0	0.0	0.0	2.1	1.0	0.0	2.1	1.0	0.0	R=	17.2		
	0.7	22.3	0.2	0.0	0.0	0.2	0.0	0.0	8.9	9.4	6.2	8.9	9.4	6.2	T=	72.4	SUM=	89.6
5	0.4	40.8	0.2	0.1	0.0	0.2	0.1	0.0	6.4	2.7	0.2	6.4	2.7	0.2	R=	60.3		
	9.5	95.2	1.9	0.3	0.0	1.9	0.3	0.0	19.8	2.4	2.8	19.8	2.4	2.8	T=	159.1	SUM=	219.4
6	0.0	64.0	0.0	0.1	0.0	0.0	0.1	0.0	5.7	5.6	0.1	5.7	5.6	0.1	R=	86.9		
	10.3	70.1	0.9	0.2	0.0	0.9	0.2	0.0	29.5	2.4	2.2	29.5	2.4	2.2	T=	150.5	SUM=	237.5
7	1.8	47.5	1.1	0.3	0.1	1.1	0.3	0.1	11.0	1.7	0.2	11.0	1.7	0.2	R=	78.2		
	23.6	150.6	5.6	0.2	0.1	5.6	0.2	0.1	34.6	1.9	1.3	34.6	1.9	1.3	T=	261.9	SUM=	340.1
8	1.4	30.3	0.3	0.2	0.0	0.3	0.2	0.0	4.3	2.5	0.1	4.3	2.5	0.0	R=	46.3		
	27.2	148.7	5.6	1.1	0.1	5.6	1.1	0.1	28.5	1.3	0.6	28.5	1.3	0.3	T=	250.0	SUM=	296.3
9	0.6	27.6	0.5	0.2	0.0	0.5	0.2	0.0	3.5	2.1	0.2	3.4	1.6	0.2	R=	40.6		
	33.0	175.1	6.2	0.9	0.1	6.2	0.9	0.1	35.3	4.7	1.2	33.5	4.8	0.8	T=	302.7	SUM=	343.4
10	0.0	39.8	0.4	0.1	0.0	0.4	0.1	0.0	4.2	1.5	0.0	3.8	1.8	0.0	R=	52.3		
	33.4	158.9	7.1	1.4	0.2	7.1	1.4	0.2	39.8	7.0	3.3	38.3	5.3	2.2	T=	305.5	SUM=	357.8
11	6.0	0.0	0.7	0.2	0.0	0.7	0.2	0.0	0.7	1.5	0.0	6.0	0.0	1.2	R=	17.2		
	25.6	234.8	5.5	2.1	0.4	5.5	2.1	0.4	2.7	2.1	1.3	5.1	9.1	0.6	T=	297.3	SUM=	314.5
12	1.1	81.4	0.2	0.4	0.0	0.2	0.4	0.0	20.3	1.5	0.3	17.2	2.9	0.2	R=	126.0		
	51.4	156.2	11.2	5.7	1.3	11.2	5.7	1.3	48.5	10.2	4.3	50.9	0.3	3.8	T=	362.1	SUM=	488.1
13	0.1	26.0	0.8	0.1	0.0	0.8	0.1	0.0	1.6	1.9	0.1	3.0	1.5	0.1	R=	36.2		
	25.2	166.1	7.1	1.0	0.3	7.1	1.0	0.3	49.3	12.8	3.1	45.7	12.6	1.9	T=	333.3	SUM=	369.5
14	0.5	26.1	0.1	0.2	0.2	0.1	0.2	0.2	2.7	0.7	0.1	2.2	0.9	0.1	R=	34.3		
	31.2	166.5	5.7	1.2	0.2	5.7	1.2	0.2	39.4	9.6	3.2	37.2	8.8	1.3	T=	311.4	SUM=	345.7
15	0.8	26.9	0.4	0.1	0.0	0.4	0.1	0.0	0.4	0.5	0.0	0.3	0.4	0.1	R=	30.6		
	22.9	133.7	4.9	0.8	0.1	4.9	0.8	0.1	31.6	9.2	2.0	34.0	10.1	2.5	T=	257.5	SUM=	288.1
16	0.0	3.4	0.4	0.3	0.0	0.4	0.3	0.0	0.2	0.0	0.1	0.1	9.0	4.0	R=	18.1		
	26.8	140.3	6.5	1.1	0.1	6.5	1.1	0.1	22.9	9.0	6.2	18.8	6.1	12.3	T=	257.8	SUM=	275.9
17	0.1	35.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.6	0.0	0.2	0.7	R=	37.0		
	19.1	139.6	3.2	2.9	0.1	3.2	2.9	0.1	39.2	16.5	4.5	35.2	22.3	8.5	T=	297.3	SUM=	334.3
18	0.1	2.3	0.3	0.1	0.0	0.3	0.1	0.0	0.3	0.2	0.0	0.2	0.3	0.0	R=	4.2		
	13.6	87.6	3.3	0.5	0.0	3.3	0.5	0.0	26.9	16.6	7.1	28.7	17.1	7.2	T=	212.6	SUM=	216.7
19	0.1	0.2	0.0	0.2	0.1	0.5	0.0	0.0	2.9	0.4	1.4	2.2	0.2	0.3	R=	8.4		
	13.3	60.9	4.1	2.0	0.3	2.8	1.0	0.3	28.7	23.2	9.1	19.0	15.4	7.8	T=	187.6	SUM=	196.0
20	0.0	0.4	0.1	0.0	0.0	0.1	0.0	0.0	0.8	0.3	0.0	0.9	0.4	0.0	R=	3.1		
	5.2	28.2	1.1	0.2	0.0	1.2	0.2	0.0	8.3	6.9	3.8	8.0	6.4	3.4	T=	72.8	SUM=	75.9
21	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	R=	0.3		
	1.2	5.1	0.1	0.0	0.0	0.1	0.0	0.0	1.3	0.4	0.0	1.1	0.2	0.1	T=	9.7	SUM=	10.0
22																		

DELFECTIONS OF RAIL JULIANNE McNAMARA TRIAL 2

FRAME #	X	Y	LINEAR (cm)
1	0.03	0.69	0.69
2	0.36	1.19	1.25
3	0.05	0.74	0.74
4	0.25	0.61	0.66
5	0.20	0.66	0.69
6	1.91	1.27	2.29
7	1.85	1.30	2.26
8	2.21	1.55	2.70
9	3.63	0.48	3.66
10	3.20	2.36	3.98
11	2.01	3.91	4.40
12	1.83	3.56	4.00
13	1.78	4.52	4.86
14	0.41	3.38	3.40
15	1.35	4.34	4.55
16	3.00	2.59	3.96
17	3.28	2.49	4.11
18	3.40	2.31	4.11
19	2.34	1.60	2.83
20	1.42	1.24	1.89
21	0.41	1.24	1.31
22	0.00	0.76	0.76

APPENDIX J

Raw Data Variables for Subject AD

ANGULAR KINEMATICS: CENTER OF MASS

ANGELA DAÇUISTA TRIAL 1

FRAME #	CM COORDINATES X	CM COORDINATES Y	LINEAR DISTANCE CM TO HE (cm)	TIME sec	DISPLACEMENT rad	VELOCITY rad/sec
1	21.1361	32.0793	39.8433			
2	20.5720	35.3898	51.9331	0.1050	-0.0225	-0.2146
3	20.5061	37.3392	58.8450	0.1050	-0.0249	-0.2367
4	19.9420	37.1945	58.8132	0.1890	0.0358	0.1892
5	18.9776	35.4388	53.7774	0.1365	0.0925	0.6774
6	16.0638	26.7983	34.6870	0.2520	0.6322	2.5086
7	16.0204	26.3334	33.9115	0.0105	0.0437	4.1609
8	15.8073	25.7982	33.6225	0.0105	0.0611	5.8144
9	15.4589	20.7566	31.0593	0.0945	0.5670	5.9998
10	16.3178	16.1836	33.7108	0.0735	0.5188	7.0589
11	18.0009	13.0144	37.4223	0.0525	0.3516	6.6964
12	18.4502	12.6004	37.7577	0.0105	0.0580	5.5280
13	18.6642	11.8686	39.6345	0.0105	0.0521	4.9641
14	24.3918	10.6536	38.9846	0.0840	0.5446	6.4836
15	27.2338	11.2483	38.5925	0.0420	0.2711	6.4546
16	32.2302	16.8449	33.9626	0.1050	0.7556	7.1958
17	32.5717	17.5389	33.9292	0.0105	0.0823	7.8418
18	33.0187	18.2501	34.4631	0.0105	0.0874	8.3233
19	33.1456	24.8512	35.1737	0.0945	0.6990	7.3966
20	29.5413	33.6226	48.3205	0.1995	0.7877	3.9482
21	25.6398	38.6490	62.4569	0.4410	0.3315	0.7518
22	25.4469	40.5855	69.3708	0.1995	0.0194	0.0973

****

ANGULAR KINEMATICS: CENTER OF MASS ANGELA DAQUISTA TRIAL

****

BETWEEN FRAMES	TIME sec	DISPLACEMENT rad	VELOCITY rad/sec
HIGHEST CAST TO HIPS AT HB LEVEL			
1 TO 6	0.7875	0.7130	0.9054
HIPS AT HB LEVEL			
6 TO 8	0.0210	0.1047	4.9877
HIPS AT HB LEVEL TO HIPS BELOW HB			
6 TO 11	0.2415	1.5421	6.3855
HIPS BELOW HB			
11 TO 13	0.0210	0.1102	5.2461
HIPS BELOW HB TO HIPS AT HB LEVEL			
11 TO 16	0.2520	1.6814	6.6724
HIPS AT HB LEVEL			
16 TO 18	0.0210	0.1697	8.0826
HIPS AT LEVEL OF HB TO FINISH			
16 TO 22	0.9555	2.0073	2.1008

************** DATA FOR ANGLE/ANGLE DIAGRAM **************

ANGELA DAQUISTA TRIAL 1

****

FRAME #	SHOULDER ANGLE (IN RADIANS)	HIP ANGLE (IN RADIANS)
1	1.0408 (59.6339)	0.0656 (3.7578)
2	1.8458 (105.7561)	0.7728 (44.2771)
3	2.3954 (137.2448)	1.2387 (70.9702)
4	2.7539 (157.7858)	1.9411 (111.2149)
5	2.4975 (143.0987)	2.4789 (142.0312)
6	1.4175 (81.2163)	2.6358 (151.0198)
7	1.4479 (82.9607)	2.6143 (149.7899)
8	1.4079 (80.6685)	2.5906 (148.4322)
9	1.1311 (64.8051)	2.6203 (150.1335)
10	1.1541 (66.1240)	2.6678 (152.8564)
11	0.9992 (57.2482)	2.8636 (164.0744)
12	0.9933 (56.9143)	2.8836 (165.2208)
13	0.9775 (56.0068)	2.8971 (165.9949)
14	0.9577 (54.8743)	3.1244 (179.0134)
15	0.7751 (44.4105)	2.9562 (169.3788)
16	0.6443 (36.9139)	2.5597 (146.6615)
17	0.6780 (38.8481)	2.4844 (142.3442)
18	0.7329 (41.9931)	2.3962 (137.2940)
19	1.1208 (64.2190)	2.3623 (135.3497)
20	1.7224 (98.6892)	1.7399 (99.6918)
21	2.4808 (142.1417)	0.9355 (53.6004)
22	3.0334 (173.8017)	0.6197 (35.5079)

ANGELA DAQUISTA   TRIAL 1   26.8 Kg

		LOC	Hr	Wr	Ir	Hcm	Wcm	Icm
1	0.00	-6.71	-9.60	-1.33	7.22	-9.08	-4.89	1.86
2	0.11	-3.87	-5.45	-0.57	9.59	-4.18	-2.31	1.80
3	0.21	0.18	2.93	0.29	10.20	1.05	0.75	1.40
4	0.40	5.81	14.01	1.55	9.04	8.53	9.00	0.95
5	0.54	-9.00	4.90	0.97	5.03	-8.94	-23.22	0.39
6	0.79	19.16	38.02	10.25	3.71	24.81	43.17	0.57
7	0.80	11.84	34.09	9.40	3.63	16.53	28.54	0.58
8	0.81	14.46	34.25	11.03	3.11	18.57	36.60	0.51
9	0.90	14.51	38.62	12.17	3.17	19.54	37.83	0.52
10	0.98	15.39	42.78	11.04	3.87	20.28	36.64	0.55
11	1.03	22.97	50.87	11.58	4.39	29.42	50.56	0.58
12	1.04	1.11	25.75	5.58	4.61	5.16	8.95	0.58
13	1.05	15.87	45.05	10.41	4.33	19.98	42.74	0.47
14	1.13	12.92	41.86	9.36	4.47	16.13	32.51	0.50
15	1.18	12.62	37.35	10.64	3.51	14.85	35.99	0.41
16	1.28	4.15	30.57	8.38	3.65	5.96	12.40	0.48
17	1.29	10.10	39.02	10.53	3.71	12.45	25.28	0.49
18	1.30	2.93	25.37	7.41	3.42	3.72	7.59	0.49
19	1.40	-5.82	8.63	1.93	4.48	-6.98	-12.02	0.58
20	1.60	1.61	6.42	0.75	8.58	1.49	1.46	1.02
21	2.04	-1.54	-0.80	-0.06	12.91	-2.06	-1.05	1.96

ANGELA DAQUISTA TRIAL 1 27 Kg

ENERGY IN JOULE

	HN	T	RUA	RLA	RH	LUA	LLA	LH	RT	RLL	RF	LT	LLL	LF				
1	0.0	20.7	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.1	0.2	0.1	R=	21.5		
	0.4	9.1	0.1	0.0	0.0	0.1	0.0	0.0	4.7	1.0	0.1	4.8	1.1	0.1	T=	21.5	SUM=	42.9
2	0.0	8.4	0.1	0.0	0.0	0.1	0.0	0.0	0.1	0.1	0.0	0.4	0.2	0.0	R=	9.4		
	0.7	5.6	0.1	0.0	0.0	0.1	0.0	0.0	1.4	0.2	0.1	0.9	0.2	0.1	T=	9.3	SUM=	18.7
3	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.3	0.1	0.5	0.2	0.0	R=	1.8		
	0.3	0.6	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.4	0.5	0.0	0.4	0.4	T=	2.7	SUM=	4.5
4	0.0	5.8	0.0	0.0	0.0	0.0	0.0	0.0	2.1	0.7	0.1	1.8	0.8	0.1	R=	11.3		
	0.1	3.4	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.6	1.3	0.8	1.8	1.3	T=	11.3	SUM=	22.6
5	0.4	22.0	0.1	0.0	0.0	0.1	0.0	0.0	1.4	0.8	0.0	1.4	0.8	0.0	R=	27.1		
	1.3	18.1	0.2	0.0	0.0	0.2	0.0	0.0	5.7	0.7	0.3	4.9	0.3	0.3	T=	31.9	SUM=	59.0
6	2.6	96.6	1.0	0.2	0.0	1.0	0.2	0.0	1.3	1.8	0.7	3.3	2.3	0.3	R=	111.3		
	17.1	35.5	1.3	0.0	0.0	1.3	0.0	0.0	5.7	0.1	0.0	3.6	0.3	2.0	T=	67.0	SUM=	178.3
7	0.4	32.4	0.3	0.1	0.1	0.3	0.1	0.1	2.3	2.6	0.1	0.6	5.2	0.2	R=	44.6		
	10.3	39.7	1.2	0.1	0.0	1.2	0.1	0.0	12.3	1.4	1.6	8.0	0.0	0.4	T=	76.5	SUM=	121.1
8	1.2	48.6	0.3	0.2	0.0	0.3	0.2	0.0	4.2	1.7	0.1	2.8	1.5	0.1	R=	61.5		
	15.6	35.3	1.8	0.2	0.0	1.8	0.2	0.0	6.7	0.5	0.6	5.4	0.5	0.8	T=	69.3	SUM=	130.8
9	1.3	41.2	0.8	0.2	0.0	0.8	0.2	0.0	4.5	4.3	0.2	6.6	2.5	0.1	R=	62.8		
	26.1	46.0	3.1	0.3	0.0	3.1	0.3	0.0	5.3	2.9	3.2	4.8	3.0	3.3	T=	101.6	SUM=	164.4
10	0.1	46.4	0.4	0.3	0.0	0.4	0.3	0.0	8.8	4.2	0.0	6.7	4.1	0.1	R=	71.9		
	19.8	43.6	3.2	0.5	0.1	3.2	0.5	0.1	4.8	8.4	5.8	5.8	8.6	5.9	T=	110.3	SUM=	182.2
11	0.8	133.0	0.6	0.2	0.0	0.6	0.2	0.0	5.0	4.4	0.8	5.5	6.0	0.8	R=	157.8		
	24.1	31.9	3.4	0.4	0.0	3.4	0.4	0.0	6.7	6.2	6.8	2.1	10.7	7.8	T=	104.0	SUM=	261.8
12	2.3	4.5	1.4	0.1	0.0	1.4	0.1	0.0	10.7	1.4	0.0	4.0	7.1	0.1	R=	33.0		
	22.4	45.0	3.0	0.2	0.1	3.0	0.2	0.1	3.7	16.1	8.6	1.7	10.8	8.5	T=	123.4	SUM=	156.4
13	0.5	55.2	0.5	0.1	0.0	0.5	0.1	0.0	5.4	3.4	0.1	5.7	2.7	0.1	R=	74.3		
	17.6	39.4	2.4	0.3	0.0	2.4	0.3	0.0	6.1	8.7	6.3	8.9	10.7	5.8	T=	108.9	SUM=	183.2
14	0.5	40.3	0.5	0.2	0.0	0.5	0.2	0.0	1.9	1.1	0.0	2.5	1.4	0.0	R=	49.1		
	18.2	34.7	3.3	0.6	0.1	3.3	0.6	0.1	8.2	7.1	3.9	6.1	6.5	3.9	T=	96.5	SUM=	145.7
15	1.4	44.2	0.5	0.2	0.0	0.5	0.2	0.0	0.9	0.1	0.1	1.0	0.3	0.1	R=	49.3		
	25.3	40.4	2.8	0.4	0.0	2.8	0.4	0.0	7.8	5.8	2.8	7.8	4.2	1.7	T=	102.2	SUM=	151.6
16	0.6	2.7	1.1	0.0	0.0	1.1	0.0	0.0	0.0	2.0	0.0	1.1	0.0	0.1	R=	8.7		
	20.7	53.3	2.3	0.2	0.2	2.3	0.2	0.2	12.2	7.2	1.4	5.0	2.9	1.0	T=	109.3	SUM=	118.0
17	0.0	36.5	0.4	1.1	0.0	0.4	1.1	0.0	2.9	0.8	0.0	0.1	0.6	0.2	R=	44.3		
	21.9	62.3	4.8	0.8	0.4	4.8	0.8	0.4	10.0	1.8	0.8	8.3	5.4	4.5	T=	127.1	SUM=	171.4
18	0.4	2.2	0.4	0.1	0.0	0.4	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.1	R=	3.7		
	12.6	36.9	1.7	0.2	0.0	1.7	0.2	0.0	9.4	5.0	1.9	10.0	6.2	2.9	T=	88.7	SUM=	92.4
19	0.0	6.6	0.0	0.1	0.0	0.0	0.1	0.0	1.9	1.3	0.1	1.1	0.6	0.0	R=	11.8		
	3.1	13.8	1.0	0.3	0.0	1.0	0.3	0.0	5.5	5.2	2.8	4.6	3.6	1.6	T=	42.8	SUM=	54.6
20	0.0	0.4	0.1	0.0	0.0	0.1	0.0	0.0	0.2	0.1	0.0	0.1	0.0	0.0	R=	0.9		
	0.4	2.2	0.1	0.0	0.0	0.1	0.0	0.0	0.5	0.8	0.6	0.6	0.9	0.6	T=	6.8	SUM=	7.7
21	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	R=	1.2		
	0.2	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.2	0.1	0.1	T=	1.9	SUM=	3.1
22																		

DELFECTIONS OF RAIL ANGELA DAQUISTA TRIAL 1

FRAME #	X	Y	LINEAR (cm)
1	0.13	1.32	1.33
2	0.33	1.27	1.31
3	0.18	0.86	0.88
4	0.18	1.30	1.31
5	0.03	1.24	1.24
6	0.18	1.45	1.46
7	0.03	1.50	1.50
8	0.03	1.47	1.47
9	0.86	1.52	1.75
10	1.55	0.71	1.70
11	2.08	0.48	2.14
12	1.91	0.41	1.95
13	1.91	0.66	2.02
14	0.86	1.70	1.91
15	0.05	2.82	2.82
16	1.19	1.65	2.04
17	0.97	1.24	1.58
18	1.40	1.80	2.28
19	1.57	0.86	1.80
20	0.48	1.42	1.50
21	0.08	1.04	1.04
22	0.18	1.35	1.36

APPENDIX K

Computer Programs

```
0: dsp "STALDER PROGRAMS";wait 2000
1: dsp "DATA DIGITIZING + STORAGE";wait 1500
2: prt "DETERMINE SCALE FOR PLOT"
3: dsp "DIGI LOWER LEFT CORNER";red 4,X,Y;2.54X→X;2.54Y→Y;beep
4: dsp "DIGI UPPER RIGHT CORNER";red 4,A,B;2.54A→A;2.54B→B;beep
5: (A-X)/29.25→r0→S;(B-Y)/15.24→r1
6: if r0>r1;r1→S
7: fxd 4;prt "SCALE  1-",1/S→S
8: dim A[22,28],B[22,28],C[27],Z$[23,36],K$[14,11]
9: S→C[26]
10: "HEAD + NECK"→K$[1];"TRUNK"→K$[2];"R.UPPER ARM"→K$[3]
11: "R.LOWER ARM"→K$[4];"R. HAND"→K$[5];"L.UPPER ARM"→K$[6]
12: "L.LOWER ARM"→K$[7];"L. HAND"→K$[8];"R. THIGH"→K$[9]
13: "R.LOWER LEG"→K$[10];"R. FOOT"→K$[11];"L. THIGH"→K$[12]
14: "L.LOWER LEG"→K$[13];"L. FOOT"→K$[14]
15: dsp "DIGITIZE HEIGHT OF HIGH BAR";red 4,X,Y;wait 50;beep
16: 2.54X→C[24];2.54Y→C[25]
17: ent "DIGITIZE REFERENCE ? [1=YES]",r0
18: if r0#1;ent "CORRECTION FACTOR =?",C[1]
19: if r0=1;gsb "corfac"
20: ent "COMMENT",Z$[1]
21: 1→A;ent "NUMBER OF FRAMES ? [UP TO 22]",N
22: if N>22;dsp "MAXIMUM IS 22 FRAMES !!!";wait 2000;jmp -1
23: ent "DESCRIPTION OF FRAME",Z$[A+1]
24: if A>1;fxd 0;dsp "TIME INTERVAL FRAMES",A-1,A;wait 1500;ent "T=",C[A]
25: for B=1 to 14
26: 0→r2
27: if B=4;1→r2
28: if B=5;1→r2
29: if B=7;1→r2
30: if B=8;1→r2
31: if B=10;1→r2
32: if B=13;1→r2
33: if r2=1;gto 35
34: dsp "PROXIMAL",K$[B];red 4,X,Y;2.54X→X;2.54Y→Y;beep;wait 300
35: if r2=1;E→X;F→Y
36: X→A[A,B];Y→A[A,B+14]
37: dsp "DISTAL",K$[B];red 4,E,F;2.54E→E;2.54F→F;beep;wait 300
38: E→B[A,B];F→B[A,B+14]
39: next B
40: 0→r4→r5→r6→r7
41: ent "ERROR ?? [1=YES]",r7
42: if r7=1;dsp "DIGITIZE FRAME AGAIN";wait 3000;gto 25
43: ent "ADJUST COORDS. UP EXTREM.? [1=YES]",r4
44: if r4#1;gto 53
45: if r4=1;1→B
46: B[A,B]→A[A,B+1];B[A,B+14]→A[A,B+15]
47: A[A,B+5]→A[A,B+2];A[A,B+19]→A[A,B+16]
48: B[A,B+5]→B[A,B+2]→A[A,B+3]→A[A,B+6]
49: B[A,B+19]→B[A,B+16]→A[A,B+17]→A[A,B+20]
50: B[A,B+6]→B[A,B+3]→A[A,B+4]→A[A,B+7]
*9113
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```
51: B[A,B+20]→B[A,B+17]→A[A,B+18]→A[A,B+21]
52: B[A,B+7]→B[A,B+4];B[A,B+21]→B[A,B+18]
53: ent "ADJUST COORDS. LOW EXTREM.? [1=YES]",r5
54: if r5#1;gto 60
55: if r5=1;1→B
56: A[A,B+11]→A[A,B+8];A[A,B+25]→A[A,B+22]
57: B[A,B+11]→B[A,B+8]→A[A,B+12]→A[A,B+9]
58: B[A,B+25]→B[A,B+22]→A[A,B+26]→A[A,B+23]
59: B[A,B+12]→B[A,B+9];B[A,B+26]→B[A,B+23]
60: ent "ADJUST COORDS FOOT? [1=YES]",r6
61: if r6#1;gto 65
62: if r6=1;1→B
63: A[A,B+13]→A[A,B+10];A[A,B+27]→A[A,B+24]
64: B[A,B+13]→B[A,B+10];B[A,B+27]→B[A,B+24]
65: 1+A→A;if A<=N;gto 23
66: gsb "store"
67: dsp "STORAGE DONE";end
68: "corfac":
69: dsp "DIGITIZE POINT 1";red 4,X,Y;wait 100;2.54X→X;2.54Y→Y;beep
70: dsp "DIGITIZE POINT 2";red 4,K,L;wait 100;2.54K→K;2.54L→L;beep
71: ent "REAL SIZE OF REFERENCE [cm]",O
72: fxd 2;prt "Cfator",O/√((K-X)^2+(L-Y)^2)→C[1]
73: ret
74: "store":
75: ent "TRACK TO BE USED? [0=0, 1=1]",r8
76: if r8=0;trk 0
77: if r8=1;trk 1
78: N→C[27]
79: ent "FILENUMBER TO BE RECORDED ?",Q
80: rcf Q,A[*],B[*],C[*]
81: rcf Q+1,Z$,K$
82: trk 0
83: wtb 7,10,10,10,10,10,10,13
84: fmt ,9x,18"*",x,c20,x,17"*",/,/
85: wrt 7,"FILE CONTENTS RECORD"
86: fmt 1,9x,c10,c36,c8,f2.0
87: wrt 7.1,"DATA SPEC:",Z$[1],"IN FILE",Q
88: wtb 7,10,10,13
89: fmt 2,9x,c7,f3.0,c46,/
90: for J=1 to 22
91: wrt 7.2,"FRAME #",J,Z$[J+1]
92: next J
93: fmt 3,/,/,9x,c10;wrt 7.3,"COMMENTS :"
94: wtb 7,12
95: ret
*28964
```

```
0: dsp "RAW DATA  RETRIEVAL";wait 1500
1: ent "FILE # TO BE RETRIEVED",Q
2: dim A[22,28],B[22,28],C[27],Z$[23,36],K$[14,11]
3: ent "TRACK TO BE USED [0=0,1=1]",r9
4: if r9=0;trk 0
5: if r9=1;trk 1
6: ldf Q,A[*],B[*],C[*]
7: ldf Q+1,Z$,K$
8: trk 0
9: wtb 7,13,10,10,10,10,10,10
10: fmt 1,14x,c50,/;fmt 2,14x,c17,f7.4,/;fmt 3,14x,10f7.4
11: fmt 6,14x,18"*",x,c24,x,f2.0,x,18"*",/,/
12: wrt 7.6,"DATA RETRIEVAL SUBJECT #",Q
13: fmt 14x,c65,/;fmt 5,14x,65"*",/;wrt 7.5
14: wrt 7.1,Z$[1];wrt 7.5
15: wrt 7.2,"Correctionfactor=",C[1]
16: wrt 7.1,"Time Interval between the Frames (sec.)            "
17: fmt 4,9x,10f7.0;wrt 7.4,1,2,3,4,5,6,7,8,9,10
18: wrt 7.3,C[2],C[3],C[4],C[5],C[6],C[7],C[8],C[9],C[10];wtb 7,10
19: wrt 7.4,10,11,12,13,14,15,16,17,18,19
20: wrt 7.3,C[11],C[12],C[13],C[14],C[15],C[16],C[17],C[18],C[19];wtb 7,10
21: fmt 5,9x,4f7.0;wrt 7.5,19,20,21,22
22: fmt 6,14x,3f7.4;wrt 7.6,C[20],C[21],C[22]
23: fmt 6,/,14x,65"-",2/;wrt 7.6
24: wtb 7,12;0→r0
25: for A=1 to C[27]
26: gsb "printout"
27: if A=C[27];wtb 7,12;dsp "RAWDATA OUTPUT DONE";end
28: next A
29: "printout":
30: if r0=2;0→r0;wtb 7,12
31: wtb 7,13,10,10,10,10,10,10
32: fmt 1,10x,7c9;fmt 2,/;fmt 3,9x,7f9.2;fmt 4,/,10x,c63
33: fmt 5,14x,c16,x,f2.0;wrt 7.5,"RAW DATA FRAME #",A
34: wrt 7.4,Z$[A+1];wrt 7.2
35: wrt 7.1,"HNeck","Trunk","RUarm","RLarm","Rhand","LUarm","LLarm"
36: wrt 7.5,"PROX.  ENDPOINTS"
37: wrt 7.3,"X",A[A,1],A[A,2],A[A,3],A[A,4],A[A,5],A[A,6],A[A,7]
38: wrt 7.3,"Y",A[A,15],A[A,16],A[A,17],A[A,18],A[A,19],A[A,20],A[A,21]
39: wrt 7.5,"DISTAL ENDPOINTS"
40: wrt 7.3,"X",B[A,1],B[A,2],B[A,3],B[A,4],B[A,5],B[A,6],B[A,7]
41: wrt 7.3,"Y",B[A,15],B[A,16],B[A,17],B[A,18],B[A,19],B[A,20],B[A,21]
42: wrt 7.2
43: wrt 7.1,"Lhand","RUleg","RLleg","Rfoot","LUleg","LLleg","Lfoot"
44: wrt 7.5,"PROX.  ENDPOINTS"
45: wrt 7.3,"X",A[A,8],A[A,9],A[A,10],A[A,11],A[A,12],A[A,13],A[A,14]
46: wrt 7.3,"Y",A[A,22],A[A,23],A[A,24],A[A,25],A[A,26],A[A,27],A[A,28]
47: wrt 7.5,"DISTAL ENDPOINTS"
48: wrt 7.3,"X",B[A,8],B[A,9],B[A,10],B[A,11],B[A,12],B[A,13],B[A,14]
49: wrt 7.3,"Y",B[A,22],B[A,23],B[A,24],B[A,25],B[A,26],B[A,27],B[A,28]
50: r0+1→r0
51: ret
*1148
```

```
0: dsp "EDIT DATAFILE";wait 1500
1: ent "FILE # TO BE EDITED ?",Q
2: dim A[22,28],B[22,28],C[27],Z$[23,36],K$[14,11]
3: ent "TRACK TO BE USED? [0=0,1=1]",r8
4: if r8=0;trk 0
5: if r8=1;trk 1
6: ldf Q,A[*],B[*],C[*];ldf Q+1,Z$,K$;trk 0
7: fxd 0;dsp "YOU ARE NOW EDITING FILE #",Q;wait 1500
8: ent "DIGITIZE REFERENCE ? [1=YES]",r0
9: if r0=1;gsb "cfac"
10: if r0#1;ent "CORRECTIONFACTOR =",C[1]
11: ent "COMMENT",Z$[1]
12: ent "FRAME # TO EDIT ? [0=STOP]",A
13: if A>22;dsp "NO SPACE LEFT. START A NEW FILE";end
14: if A=0;gsb "store"
15: if A=0;dsp "EDIT DONE";end
16: ent "DESCRIPTION OF FRAME",Z$[A+1]
17: if A>1;fxd 0;dsp "TIME INTERVAL FRAMES",A-1,A;wait 1500;ent "T=",C[A]
18: fxd 4;for B=1 to 14
19: 0→r2
20: if B=4;1→r2
21: if B=5;1→r2
22: if B=7;1→r2
23: if B=8;1→r2
24: if B=10;1→r2
25: if B=13;1→r2
26: if r2=1;gto 28
27: dsp "PROXIMAL",K$[B];red 4,X,Y;2.54X→X;2.54Y→Y;beep;wait 300
28: if r2=1;E→X;F→Y
29: X→A[A,B];Y→A[A,B+14]
30: dsp "DISTAL",K$[B];red 4,E,F;2.54E→E;2.54F→F;beep;wait 300
31: E→B[A,B];F→B[A,B+14]
32: next B
33: ent "ERROR ?? [1=YES]",r0
34: if r0=1;dsp "DIGITIZE FRAME AGAIN";wait 3000;gto 18
35: gto 12
36: "cfac":
37: dsp "DIGITIZE POINT 1";red 4,X,Y;wait 100;2.54X→X;2.54Y→Y;beep
38: dsp "DIGITIZE POINT 2";red 4,K,L;wait 100;2.54K→K;2.54L→L;beep
39: ent "REAL SIZE OF REFERENCE [cm]",O
40: fxd 2;prt "Cfator",O/√((K-X)^2+(L-Y)^2)→D[1]
41: ret
42: "store":
43: ent "# FRAMES ADDED ?",P;P+C[27]→C[27]
44: ent "FILENUMBER TO BE RECORDED ?",Q
45: ent "TRK TO BE USED? [0=0,1=1]",r9
46: if r9=0;trk 0
47: if r9=1;trk 1
48: rcf Q,A[*],B[*],C[*]
49: rcf Q+1,Z$,K$
50: trk 0
*23287
```

```
51: wtb 7,13,10,10,10,10,10,10
52: fmt ,9x,18"*",x,c20,x,17"*",/,/
53: wrt 7,"FILE CONTENTS RECORD"
54: fmt 1,9x,c10,c36,c6,f2.0
55: wrt 7.1,"DATA SPEC:",Z$[1],"IN FILE",Q
56: wtb 7,10,10,13
57: fmt 2,9x,c7,f3.0,c46,/
58: for J=1 to 22
59: wrt 7.2,"FRAME #",J,Z$[J+1]
60: next J
61: fmt 3,/,/,9x,c10;wrt 7.3,"COMMENTS :"
62: wtb 7,12
63: ret
*27879
```

```
0: dsp "CENTER OF MASS KINEMATICS";wait 1500
1: dim A[22,28],B[22,28],C[27],R[22,1],A$[50],K$[14,11]
2: dim S[14],M[14],X[22,1],Y[22,1],J[22,1]
3: ent "TRIAL ID?",A$
4: wtb 7,12
5: fmt 1,10x,120"*",/;wrt 7.1
6: fmt 2,20x,c35,10x,c50;wrt 7.2,"ANGULAR KINEMATICS:  CENTER OF MASS",A$
7: wrt 7.1;wtb 7,10,10
8: fmt 3,20x,c20,c20,c10;wrt 7.3,"CM COORDINATES","LINEAR DISTANCE","TIME"
9: fmt 4,70x,3c20
10: wtb 7,27,10;wrt 7.4,"DISPLACEMENT","VELOCITY","ACCELERATION"
11: fmt 5,10x,c10,c10,c10,c20
12: wrt 7.5,"FRAME # ","X","Y","CM TO HB (cm)"
13: fmt 6,60x,c10,3c20,/,/,/;wtb 7,27,10
14: wrt 7.6,"sec","rad","rad/sec","rad/sec/sec"
15: fxd 4
16: "HEAD+NECK"→K$[1];"TRUNK"→K$[2];"R.UPPER ARM"→K$[3];"R. ARM"→K$[4]
17: "R. HAND"→K$[5];"L.UPPER ARM"→K$[6];"L. ARM"→K$[7];"L. HAND"→K$[8]
18: "R. THIGH"→K$[9];"R. LEG"→K$[10];"R. FOOT"→K$[11];"L. THIGH"→K$[12]
19: "L. LEG"→K$[13];"L. FOOT"→K$[14]
20: .5→S[1]→S[2];.436→S[3]→S[6];.43→S[4]→S[7];.28→S[5]→S[8]
21: .433→S[9]→S[10]→S[12]→S[13];.45→S[11]→S[14]
22: .077→M[1];.463→M[2];.03→M[3]→M[6];.0155→M[4]→M[7]
23: .005→M[5]→M[8];.115→M[9]→M[12];.0525→M[10]→M[13]
24: .012→M[11]→M[14]
25: ent "TRK TO BE USED? [0=0,1=1]",r8
26: if r8=0;trk 0
27: if r8=1;trk 1
28: ent "FILE TO BE USED?",Q
29: ldf Q,A[*],B[*],C[*];trk 0
30: for H=1 to C[27];0→T→U
31: C[H+1]+r14→r14
32: for I=1 to 14
33: A[H,I]-B[H,I]→O;abs(O)→O;A[H,I+14]-B[H,I+14]→P;abs(P)→P
34: S[I]O→K;S[I]P→L
35: if A[H,I]<B[H,I];K+A[H,I]→E;jmp 2
36: A[H,I]-K→E
37: if A[H,I+14]<B[H,I+14];L+A[H,I+14]→F;jmp 2
38: A[H,I+14]-L→F
39: M[I]E→C;M[I]F→D;C+T→X[H,1];D+U→Y[H,1];X[H,1]→T;Y[H,1]→U
40: next I
41: √((X[H,1]-C[24])^2+(Y[H,1]-C[25])^2)→J[H,1];C[1]*J[H,1]→J[H,1]
42: next H
43: sfg 14
44: for H=1 to C[27]-1
45: (Y[H,1]-C[25])/(X[H,1]-C[24])→r0
46: (Y[H+1,1]-C[25])/(X[H+1,1]-C[24])→r1
47: atn((r1-r0)/(1+r1r0))→R[H,1]
48: R[H,1]/57.296→R[H,1]
49: next H
50: cfg 14
*25721
```

```
51: fmt 1,13x,f2.0,5x,2f10.4,f20.4,/
52: for H=1 to C[27]
53: wrt 7.1,H,X[H,1],Y[H,1],J[H,1]
54: next H
55: gsb "store"
56: dsp "PROGRAM DONE"
57: trk 0;ldf 15
58: "store":
59: 22→C[27]
60: ent "FILE TO BE RECORDED?",Q
61: trk 1;rcf Q,C[*],R[*];trk 0
62: ret
*303
```

```
0: dsp "CENTER OF MASS KINEMATICS (2)";beep;wait 1500
1: fxd 4
2: for N=1 to 7
3: wtb 7,27,10;wtb 7,27,10;wtb 7,27,10;wtb 7,27,10;wtb 7,27,10;wtb 7,27,10
4: next N
5: wtb 7,27,10
6: ent "FILE TO BE USED?",Q
7: trk 1;ldf Q,C[*],R[*];trk 0
8: for H=1 to C[27]-1
9: R[H,1]/C[H+1]→A[H,1]
10: next H
11: for H=1 to C[27]-2
12: (A[H+1,1]-A[H,1])/(C[H+1]+C[H+2])→B[H,1]
13: next H
14: fmt 2,60x,f10.4,2f20.4
15: fmt 3,110x,f20.4
16: for H=1 to C[27]-1
17: wrt 7.2,C[H+1],R[H,1],A[H,1]
18: if H<C[27]-1;wrt 7.3,B[H,1]
19: next H
20: dsp " PROGRAM DONE";end
*4184
```

```
0: dsp "BODY ANGLES:  SHOULDER/HIP";wait 1500
1: dsp "DATA FOR ANGLE ANGLE DIAGRAMS";wait 1500
2: dim A[22,28],B[22,28],C[27],A$[35]
3: fxd 4
4: ent "NUMBER OF TRIALS",N
5: for T=1 to N
6: ent "TRK TO BE USED [0=0,1=1]?",r8
7: if r8=0;trk 0
8: if r8=1;trk 1
9: ent "FILE TO BE USED?",Q
10: ent "TRIAL ID?",A$
11: ldf Q,A[*],B[*],C[*];trk 0
12: sfg 14
13: for H=1 to C[27]
14: √((B[H,3]-A[H,3])^2+(B[H,17]-A[H,17])^2)→r0
15: √((A[H,9]-A[H,3])^2+(A[H,23]-A[H,17])^2)→r1
16: √((B[H,9]-A[H,9])^2+(B[H,23]-A[H,23])^2)→r2
17: √((A[H,23]-B[H,17])^2+(A[H,9]-B[H,3])^2)→r3
18: √((B[H,9]-A[H,3])^2+(B[H,23]-A[H,17])^2)→r4
19: acs((r0^2+r1^2-r3^2)/(2*r0*r1))→A[H,3];A[H,3]/57.296→A[H,1]
20: acs((r1^2+r2^2-r4^2)/(2*r1*r2))→A[H,4];A[H,4]/57.296→A[H,2]
21: next H
22: wtb 7,12
23: fmt 1,10x,15"*",x,c28,x,15"*",/;wrt 7.1,"DATA FOR ANGLE/ANGLE DIAGRAM"
24: fmt 2,10x,c35,/;wrt 7.2,A$
25: fmt 1,10x,60"*",/,/;wrt 7.1
26: fmt 3,20x,2c25;wrt 7.3,"SHOULDER ANGLE","HIP ANGLE"
27: fmt 4,10x,c10,2c25,/,/;wrt 7.4,"FRAME # ","(IN RADIANS)","(IN RADIANS)"
28: for H=1 to C[27]
29: fmt 6,14x,f2.0,10x,f7.4,x,c1,f9.4,c1,6x,f8.4,x,c1,f9.4,c1,/
30: wrt 7.6,H,A[H,1],"(",A[H,3],")",A[H,2],"(",A[H,4],")"
31: next H
32: next T
*12238
```

```
0: dsp "BODY ANGLES:  SHOULDER/HIP";wait 1500
1: dsp "DATA FOR ANGLE ANGLE DIAGRAMS";wait 1500
2: dim A[22,28],B[22,28],C[27],A$[35]
3: fxd 4
4: ent "NUMBER OF TRIALS",N
5: for T=1 to N
6: ent "TRK TO BE USED [0=0,1=1]?",r8
7: if r8=0;trk 0
8: if r8=1;trk 1
9: ent "FILE TO BE USED?",Q
10: ent "TRIAL ID?",A$
11: ldf Q,A[*],B[*],C[*];trk 0
12: sfg 14
13: for H=1 to C[27]
14: √((B[H,3]-A[H,3])^2+(B[H,17]-A[H,17])^2)→r0
15: √((A[H,9]-A[H,3])^2+(A[H,23]-A[H,17])^2)→r1
16: √((B[H,9]-A[H,9])^2+(B[H,23]-A[H,23])^2)→r2
17: √((A[H,23]-B[H,17])^2+(A[H,9]-B[H,3])^2)→r3
18: √((B[H,9]-A[H,3])^2+(B[H,23]-A[H,17])^2)→r4
19: acs((r0^2+r1^2-r3^2)/(2*r0*r1))→A[H,3];A[H,3]/57.296→A[H,1]
20: acs((r1^2+r2^2-r4^2)/(2*r1*r2))→A[H,4];180-A[H,4]→A[H,4]
21: A[H,4]/57.296→A[H,2]
22: next H
23: ent "CORRECTIONS? [0=STOP]",C
24: if C=0;dsp "EDIT DONE";wait 1500;gto 32
25: ent "SHOULDER [1], HIP [2]",r6
26: ent " FRAME TO EDIT?",H
27: if r6=1;dsp "CURRENT SHOULDER VALUE=",A[H,3];wait 1500
28: if r6=1;ent "NEW SHOULDER VALUE=",A[H,3];A[H,3]/57.296→A[H,1]
29: if r6=2;dsp "CURRENT HIP VALUE=",A[H,4];wait 1500
30: if r6=2;ent "NEW HIP VALUE?",A[H,4];A[H,4]/57.296→A[H,2]
31: gto 23
32: wtb 7,12,13
33: fmt 1,10x,15"*",x,c28,x,15"*",/;wrt 7.1,"DATA FOR ANGLE/ANGLE DIAGRAM"
34: fmt 2,10x,c35,/;wrt 7.2,A$
35: fmt 1,10x,60"*",/,/;wrt 7.1
36: fmt 3,20x,2c25;wrt 7.3,"SHOULDER ANGLE","HIP ANGLE"
37: fmt 4,10x,c10,2c25,/,/;wrt 7.4,"FRAME # ","(IN RADIANS)","(IN RADIANS)"
38: for H=1 to C[27]
39: fmt 6,14x,f2.0,10x,f7.4,x,c1,f9.4,c1,6x,f8.4,x,c1,f9.4,c1,/
40: wrt 7.6,H,A[H,1],"(",A[H,3],")",A[H,2],"(",A[H,4],")"
41: next H
42: wtb 7,13
43: wtb 7,12;wtb 7,13
44: wtb 7,27,84;wtb 7,27,70,int(1056)/64,int(1056)
45: "angleplot":
46: wtb 7,27,65,int(420/64),int(420),int(1000/64),int(1000)
47: wtb 7,27,46,"|",int(10/64),int(10),0
48: wtb 7,27,97,int(420/64),int(420),int(240/64),int(240)
49: wtb 7,27,65,int(240/64),int(240),int(300/64),int(300)
50: wtb 7,27,46,char(95),int(10/64),int(10),9
*151
```

```
51: wtb 7,27,97,int(1250/64),int(1250),int(300/64),int(300)
52: wtb 7,27,79,int(420/64), int(420),int(300/64),int(300)
53: for H=1 to C[27]
54: A[H,2]*200→X;A[H,1]*160→Y
55: wtb 7,27,65,int(X/64), int(X),int(Y/64),int(Y)
56: wtb 7,"O",8
57: H+1→H;if H>22;gto 62
58: A[H,2]*200→X;A[H,1]*160→Y
59: wtb 7,27,46,".",int(5/64), int(5),0
60: wtb 7,27,97,int(X/64), int(X),int(Y/64),int(Y)
61: jmp -5
62: wtb 7,27,65,int(0/64),int(0),int(800/64),int(800)
63: next T
64: dsp "PROGRAM DONE!!!"
*11825
```

```
0: dsp "PATH OF CENTER OF MASS";wait 1500
1: dim A[22,28],B[22,28],C[27],S[14],M[14],A$[1,35],X[22,1],Y[22,1]
2: .5→S[1]→S[2];.436→S[3]→S[6];.43→S[4]→S[7];.28→S[5]→S[8]
3: .433→S[9]→S[10]→S[12]→S[13];.45→S[11]→S[14]
4: .096→M[1];.458→M[2];.033→M[3]→M[6];.019→M[4]→M[7];.0065→M[5]→M[8]
5: .105→M[9]→M[12];.045→M[10]→M[13];.0145→M[11]→M[14]
6: ent "NUMBER OF TRIALS?",N
7: for T=1 to N
8: ent "TRK TO BE USED [0=0,1=1]",r8
9: if r8=0;trk 0
10: if r8=1;trk 1
11: ent "FILE # TO BE USED ?",Q
12: ent "TRIAL ID?",A$[1]
13: ldf Q,A[*],B[*],C[*]
14: trk 0
15: for H=1 to C[27];0→T→U
16: C[H+1]+r14→r14
17: for I=1 to 14
18: A[H,I]-B[H,I]→O;abs(O)→O;A[H,I+14]-B[H,I+14]→P;abs(P)→P
19: S[I]O→K;S[I]P→L
20: if A[H,I]<B[H,I];K+A[H,I]→E;gto 22
21: A[H,I]-K→E
22: if A[H,I+14]<B[H,I+14];L+A[H,I+14]→F;gto 24
23: A[H,I+14]-L→F
24: M[I]E→C;M[I]F→D;C+T→X[H,1];D+U→Y[H,1];X[H,1]→T;Y[H,1]→U
25: next I
26: next H
27: wtb 7,27,84;wtb 7,27,70,int(1056/64),int(1056)
28: "cgplt":
29: wtb 7,27,65,int(240/64),int(240),int(700/64),int(700)
30: wtb 7,27,46,"|",int(10/64),int(10),0
31: wtb 7,27,97,int(240/64),int(240),int(100/64),int(100)
32: wtb 7,27,46,char(95),int(10/64),int(10),9
33: Y[1,1]*12+150→Y
34: wtb 7,27,97,int(1000/64),int(1000),int(100/64),int(100)
35: wtb 7,27,65,int(240/64),int(240),int(Y/64),int(Y)
36: for H=1 to C[27]
37: X[H,1]*15+250→X;Y[H,1]*12+150→Y
38: wtb 7,27,65,int(X/64),int(X),int(Y/64),int(Y)
39: wtb 7,"O",8
40: H+1→H;if H>22;gto 45
41: X[H,1]*15+250→X;Y[H,1]*12+150→Y
42: wtb 7,27,46,".",int(5/64),int(5),0
43: wtb 7,27,97,int(X/64),int(X),int(Y/64),int(Y)
44: jmp -5
45: wtb 7,27,65,int(0/64),int(0),int(800/64),int(800)
46: fmt 1,30x,2c25,/,/;wrt 7.1,"PATH OF CENTER OF MASS :",A$[1]
47: wtb 7,27,65,int(750/64),int(750),int(200/64),int(200)
48: wtb 7,12,13
*5500
```

```
0: dsp "CENTER OF MASS KINEMATICS";wait 1500
1: dim A[22,28],B[22,28],C[27],R[22,1],A$[50],K$[14,11]
2: dim S[14],M[14],X[22,1],Y[22,1],H$[7,35],F$[7,8]
3: fxd 4
4: "HEAD+NECK"→K$[1];"TRUNK"→K$[2];"R.UPPER ARM"→K$[3];"R. ARM"→K$[4]
5: "R. HAND"→K$[5];"L.UPPER ARM"→K$[6];"L. ARM"→K$[7];"L. HAND"→K$[8]
6: "R. THIGH"→K$[9];"R. LEG"→K$[10];"R. FOOT"→K$[11];"L. THIGH"→K$[12]
7: "L. LEG"→K$[13];"L. FOOT"→K$[14]
8: .5→S[1]→S[2];.436→S[3]→S[6];.43→S[4]→S[7];.28→S[5]→S[8]
9: .433→S[9]→S[10]→S[12]→S[13];.45→S[11]→S[14]
10: .077→M[1];.463→M[2];.03→M[3]→M[6];.0155→M[4]→M[7]
11: .005→M[5]→M[8];.115→M[9]→M[12];.0525→M[10]→M[13]
12: .012→M[11]→M[14]
13: "HIGHEST CAST TO HIPS AT HB LEVEL   "→H$[1]
14: "HIPS AT HB LEVEL                   "→H$[2]
15: "HIPS AT HB LEVEL TO HIPS BELOW HB  "→H$[3]
16: "HIPS BELOW HB                      "→H$[4]
17: "HIPS BELOW HB TO HIPS AT HB LEVEL  "→H$[5]
18: "HIPS AT HB LEVEL                   "→H$[6]
19: "HIPS AT LEVEL OF HB TO FINISH      "→H$[7]
20: ent "NUMBER OF TRIALS?",N
21: for W=1 to N
22: ent "TRIAL ID?",A$
23: ent "TRK TO BE USED? [0=0,1=1]",r8
24: if r8=0;trk 0
25: if r8=1;trk 1
26: ent "FILE TO BE USED?",Q
27: ldf Q,A[*],B[*],C[*];trk 0
28: wtb 7,12
29: fmt 1,10x,85"*",/;wrt 7.1
30: fmt 2,10x,2c35,/;wrt 7.2,"ANGULAR KINEMATICS:  CENTER OF MASS",A$;wrt 7.1
31: fmt 3,25x,c10,2c20
32: wrt 7.3,"TIME","DISPLACEMENT","VELOCITY"
33: fmt 4,10x,c15,c10,2c20,/,/
34: wrt 7.4,"BETWEEN FRAMES","sec","rad","rad/sec"
35: for G=1 to 7
36: 0→r3→r4→r5→r6
37: for H=1 to C[27];0→T→U
38: C[H+1]+r14→r14
39: for I=1 to 14
40: A[H,I]-B[H,I]→O;abs(O)→O;A[H,I+14]-B[H,I+14]→P;abs(P)→P
41: S[I]O→K;S[I]P→L
42: if A[H,I]<B[H,I];K+A[H,I]→E;jmp 2
43: A[H,I]-K→E
44: if A[H,I+14]<B[H,I+14];L+A[H,I+14]→F;jmp 2
45: A[H,I+14]-L→F
46: M[I]E→C;M[I]F→D;C+T→X[H,1];D+U→Y[H,1];X[H,1]→T;Y[H,1]→U
47: next I
48: next H
49: if G=1;for H=1 to 5
50: if G=2;for H=6 to 7
*15620
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```
51: if G=3;for H=6 to 10
52: if G=4;for H=11 to 12
53: if G=5;for H=11 to 15
54: if G=6;for H=16 to 17
55: if G=7;for H=16 to 21
56: sfg 14
57: (Y[H,1]-C[25])/(X[H,1]-C[24])→r0
58: (Y[H+1,1]-C[25])/(X[H+1,1]-C[24])→r1
59: atn((r1-r0)/(1+r1r0))→R[H,1]
60: R[H,1]/57.296→R[H,1];R[H,1]+r3→r3
61: C[H+1]+r5→r5
62: next H
63: r3/r5→r4
64: cfg 14
65: fmt 5,10x,c35,/;wrt 7.5,H$[G]
66: "1 TO 6"→F$[1];"6 TO 8"→F$[2];"6 TO 11"→F$[3];"11 TO 13"→F$[4]
67: "11 TO 16"→F$[5];"16 TO 18"→F$[6];"16 TO 22"→F$[7]
68: fmt 6,10x,c15,f10.4,2f20.4,/,/;wrt 7.6,F$[G],r5,r3,r4
69: next G
70: next W
71: dsp "PROGRAM DONE!!!!"
*13962
```

```
0: dsp "ANGULAR KINEMATICS";wait 1500
1: dim A[22,28],B[22,28],C[27],R[22,1],A$[1,35],K$[14,11]
2: dim H$[7,35],F$[7,8]
3: fxd 4
4: "HEAD+NECK"→K$[1];"TRUNK"→K$[2];"R.UPPER ARM"→K$[3];"R. ARM"→K$[4]
5: "R. HAND"→K$[5];"L.UPPER ARM"→K$[6];"L. ARM"→K$[7];"L. HAND"→K$[8]
6: "R. THIGH"→K$[9];"R. LEG"→K$[10];"R. FOOT"→K$[11];"L. THIGH"→K$[12]
7: "L. LEG"→K$[13];"L. FOOT"→K$[14]
8: "HIGHEST CAST TO HIPS AT HB LEVEL   "→H$[1]
9: "HIPS AT HB LEVEL                   "→H$[2]
10: "HIPS AT HB LEVEL TO HIPS BELOW HB  "→H$[3]
11: "HIPS BELOW HB                      "→H$[4]
12: "HIPS BELOW HB TO HIPS AT HB LEVEL  "→H$[5]
13: "HIPS AT HB LEVEL                   "→H$[6]
14: "HIPS AT LEVEL OF HB TO FINISH      "→H$[7]
15: "1 TO 6"→F$[1];"6 TO 8"→F$[2];"6 TO 11"→F$[3];"11 TO 13"→F$[4]
16: "11 TO 16"→F$[5];"16 TO 18"→F$[6];"16 TO 22"→F$[7]
17: ent "NUMBER OF TRIALS?",N
18: for W=1 to N
19: ent "TRIAL ID?",A$[1]
20: ent "TRK TO BE USED? [0=0,1=1]",r8
21: if r8=0;trk 0
22: if r8=1;trk 1
23: ent "FILE TO BE USED?",Q
24: ldf Q,A[*],B[*],C[*];trk 0
25: ent "NUMBER OF SEGEMENTS TO OUTPUT?",S
26: for T=1 to S
27: ent "SEGMENT TO OUTPUT (K$[#])?",r9
28: r9→I
29: wtb 7,12
30: fmt 1,10x,85"*",/;wrt 7.1
31: fmt 2,10x,c20,c11,c35,/
32: wrt 7.2,"ANGULAR KINEMATICS: ",K$[I],A$[1];wrt 7.1
33: fmt 3,25x,c10,2c20
34: wrt 7.3,"TIME","DISPLACEMENT","VELOCITY"
35: fmt 4,10x,c15,c10,2c20,/,/
36: wrt 7.4,"BETWEEN FRAMES","sec","rad","rad/sec"
37: for G=1 to 7
38: 0→r3→r4→r5→r6
39: if G=1;for H=1 to 5
40: if G=2;for H=6 to 7
41: if G=3;for H=6 to 10
42: if G=4;for H=11 to 12
43: if G=5;for H=11 to 15
44: if G=6;for H=16 to 17
45: if G=7;for H=16 to 21
46: r9→I
47: sfg 14
48: (A[H,I+14]-B[H,I+14])/(A[H,I]-B[H,I])→r0
49: (A[H+1,I+14]-B[H+1,I+14])/(A[H+1,I]-B[H+1,I])→r1
50: atn((r1-r0)/(1+r1r0))→R[H,1]
*2523
```

```
51: R[H,1]/57.296→R[H,1];R[H,1]+r3→r3
52: C[H+1]+r5→r5
53: next H
54: r3/r5→r4
55: cfg 14
56: fmt 5,10x,c35,/;wrt 7.5,H$[G]
57: fmt 6,10x,c15,f10.4,2f20.4,/,/;wrt 7.6,F$[G],r5,r3,r4
58: next G
59: next T
60: next W
61: dsp "PROGRAM DONE!!!!"
*522
```

```
0: dsp "ANGULAR  KINEMATICS";wait 1500
1: fxd 4
2: ent "TRK TO BE USED [0=0,1=1]?",r8
3: if r8=0;trk 0
4: if r8=1;trk 1
5: ent "FILE # TO BE USED :",Q
6: dim A[22,28],B[22,28],C[27],Z$[23,36],K$[14,11],R[22,1],A$[1,35]
7: ldf Q,A[*],B[*],C[*];ldf Q+1,Z$,K$;trk 0
8: prt " SEGMENT CODES";spc ;fmt ,f3.0,c14
9: for I=1 to 14
10: wrt 16,I,K$[I]
11: next I;spc 3
12: ent "TRIAL ID?",A$[1]
13: ent "NUMBER OF SEGMENTS TO OUTPUT?",N
14: for G=1 to N
15: ent "SEGMENT TO OUTPUT [K$[#]]?",r9
16: sfg 14
17: for H=1 to C[27]-1
18: r9→I
19: (A[H,I+14]-B[H,I+14])/(A[H,I]-B[H,I])→r0
20: (A[H+1,I+14]-B[H+1,I+14])/(A[H+1,I]-B[H+1,I])→r1
21: atn((r1-r0)/(1+r0r1))→R[H,1]
22: R[H,1]/57.296→R[H,1]
23: next H
24: cfg 14
25: for H=1 to C[27]-1
26: r9→I
27: R[H,1]/C[H+1]→A[H,I]
28: next H
29: for H=1 to C[27]-2
30: r9→I
31: (A[H+1,I]-A[H,I])/(C[H+1]+C[H+2])→B[H,I]
32: next H
33: wtb 7,12
34: fmt 1,10x,75"%",/;wrt 7.1
35: fmt 2,10x,c20,c15,c35,/;wrt 7.2,"ANGULAR KINEMATICS :",K$[I],A$[1]
36: wrt 7.1;fmt 3,/,/,20x,c5,3c20;fmt 7,10x,c10,c5,3c20,/,/
37: wrt 7.3,"TIME","DISPLACEMENT","VELOCITY","ACCELERATION"
38: wrt 7.7,"FRAME # ","sec","rad","rad/sec","rad/sec/sec"
39: fmt 4,14x,f2.0;fmt 5,20x,f6.4,2f20.4
40: fmt 6,65x,f20.4
41: for H=1 to C[27]
42: wrt 7.4,H;if H<=C[27]-1;gsb "output"
43: next H
44: next G
45: "output":
46: wrt 7.5,C[H+1],R[H,1],A[H,I]
47: if H<C[27]-1;wrt 7.6,B[H,I];wtb 7,27,10
48: ret
*24128
```

```
0: dsp "DEFLECTIONS OF RAIL";wait 1500
1: dim A[22,28],B[22,28],C[27],X[22,1],Y[22,1],L[22,1],A$[35]
2: ent "NUMBER OF TRIALS?",T
3: for G=1 to T
4: ent "TRIAL ID?",A$
5: ent "TRK TO BE USED? [0=0,1=1]",r0
6: if r0=0;trk 0
7: if r0=1;trk 1
8: ent "FILE TO BE USED?",Q
9: ldf Q,A[*],B[*],C[*];trk 0
10: wtb 7,12
11: fmt 1,10x,55"-",/;wrt 7.1
12: fmt 2,10x,c19,1x,c35;wrt 7.2,"DELFECTIONS OF RAIL",A$;wrt 7.1
13: wtb 7,10
14: fmt 3,10x,c7,7x,c1,14x,c1,12x,c11;wrt 7.3,"FRAME #","X","Y","LINEAR (cm)"
15: wtb 7,10
16: for H=1 to C[27]
17: B[H,4]-C[24]→X[H,1];abs(X[H,1])→X[H,1]
18: B[H,18]-C[25]→Y[H,1];abs(Y[H,1])→Y[H,1]
19: √(X[H,1]^2+Y[H,1]^2)→L[H,1]
20: fmt 5,13x,f2.0,3x,f8.2,5x,f8.2,8x,f8.2,/;wrt 7.5,H,X[H,1],Y[H,1],L[H,1]
21: next H
22: next G
*6744
```

```
0: dsp "ANGULAR MOMENTUM STALDER";wait 1500
1: sfg 14
2: wtb 7,27,86,int(12/64),int(12)
3: ent "MASS OF SUBJECT",r0;dim K[2,14]
4: dim A[22,28],B[22,28],C[27],S[14],M[14],E[2],G[2],Z[2],I[14],A$[80]
5: dim N$[14,6],X[22],Y[22]
6: 0→r20;1→r21
7: "HN"→N$[1];"T"→N$[2];"RUA"→N$[3];"RLA"→N$[4];"RH"→N$[5]
8: "LUA"→N$[6];"LLA"→N$[7];"LH"→N$[8];"RT"→N$[9];"RLL"→N$[10];"RF"→N$[11]
9: "LT"→N$[12];"LLL"→N$[13];"LF"→N$[14];fxd 0
10: .5→S[1]→S[2];.436→S[3]→S[6];.43→S[4]→S[7];.28→S[5]→S[8]
11: .433→S[9]→S[10]→S[12]→S[13];.45→S[11]→S[14]
12: .096→M[1];.458→M[2];.033→M[3]→M[6];.019→M[4]→M[7];.0065→M[5]→M[8]
13: .105→M[9]→M[12];.045→M[10]→M[13];.0145→M[11]→M[14]
14: .0248→I[1];1.308→I[2];.0213→I[3]→I[6];.0076→I[4]→I[7]
15: .0005→I[5]→I[8];.1052→I[9]→I[12];.0505→I[10]→I[13];.0038→I[11]→I[14]
16: fmt 8,10x,c,3x,f4.1,x,c
17: ent "SUBJECT I.D.",A$;wtb 7,10,10,10,10,10,10,13;wrt 7.8,A$,r0,"Kg"
18: wtb 7,10,10;fmt 0,c6,z
19: ent "TRK? [0=0,1=1]",r8
20: if r8=0;trk 0
21: if r8=1;trk 1
22: ent "FILE # TO BE USED ?",Q
23: ldf Q,A[*],B[*],C[*]
24: trk 0
25: fmt 4,/,19x,8c10,/;wrt 7.4,"LOC","Hr","Wr","Ir","Hcm","Wcm","Icm"
26: fmt 1,10x,f2.0,x,f6.2;fmt 2,19x,7f10.2
27: for H=1 to C[27];0→T→U
28: for S=1 to 14
29: A[H,S]-B[H,S]→O;abs(O)→O;A[H,S+14]-B[H,S+14]→P;abs(P)→P
30: S[S]O→K;S[S]P→L
31: if A[H,S]<B[H,S];K+A[H,S]→E;jmp 2
32: A[H,S]-K→E
33: if A[H,S+14]<B[H,S+14];L+A[H,S+14]→F;jmp 2
34: A[H,S+14]-L→F
35: M[S]E→C;M[S]F→D;C+T→R;D+U→Q;R→T;Q→U
36: next S
37: R→X[H];Q→Y[H]
38: next H
39: for Q=1 to 14;M[Q]r0→M[Q];next Q
40: for H=1 to C[27]-1
41: 0→r2→r4;C[H+1]→T
42: for S=1 to 14
43: 1→C
44: for F=H to H+1
45: abs(A[F,S]-B[F,S])S[S]→K
46: abs(A[F,S+14]-B[F,S+14])S[S]→L
47: if A[F,S]<B[F,S];K+A[F,S]→E[C];jmp 2
48: A[F,S]-K→E[C]
49: if A[F,S+14]<B[F,S+14];L+A[F,S+14]→G[C];jmp 2
50: A[F,S+14]-L→G[C]
*3945
```

```
51: if C=1;M[S]E[C]→r0;M[S]G[C]→r1;r0+r2→r3;r1+r4→r5;r3→r2;r5→r4
52: if A[F,S]-B[F,S]=0;9^98→Z;jmp 2
53: A[F,S]-B[F,S]→Z
54: (A[F,S+14]-B[F,S+14])/Z→Z[C]
55: C+1→C
56: next F
57: % "r32=XsCM x-x+1 ; r33=YsCM x-x+1"
58: (E[2]+E[1])/2→r32;(G[2]+G[1])/2→r33
59: % "r45=XCM AVE;r46=YCM AVE"
60: (X[H]+X[H+1])/2→r45;(Y[H]+Y[H+1])/2→r46
61: % "r34=Radius RH-sCM"
62: C[25]→r31;C[24]→r30
63: √((r33-r31)^2+(r32-r30)^2)C[1]/100→r34
64: % "r39=Radius sCM - CM"
65: √((r33-r46)^2+(r32-r45)^2)C[1]/100→r39
66: % "r35=Slope RH/sCM in x"
67: (C[25]-G[1])/(C[24]-E[1])→r35
68: % "r36=Slope RH/sCM in x+1"
69: (C[25]-G[2])/(C[24]-E[2])→r36
70: % "Slope CM sCM in x"
71: (G[1]-Y[H])/(E[1]-X[H])→r37
72: % "slope CM sCM in x+1"
73: (G[2]-Y[H+1])/(E[2]-X[H+1])→r38
74: % "r40=WsCM about RH"
75: atn((r36-r35)/(1+r35r36))/57.3/T→r40
76: % "r50=Hs about RH"
77: M[S]r34^2r40→r50
78: % "W sCM about CM"
79: atn((r38-r37)/(1+r37r38))/57.3/T→r48
80: % "H sCM CM"
81: M[S]r39^2r48→r55
82: % "r52=Local Hs"
83: (atn((Z[2]-Z[1])/(1+Z[1]Z[2]))/57.3/T)I[S]→r52
84: M[S]r34^2→r51
85: M[S]r39^2→r70
86: r55+r52→r55;r50+r52→r50
87: r50+r60→r60;r52+r62→r62;r51+r61→r61;r55+r65→r65;r70+r71→r71
88: next S
89: wrt 7.1,r21,r20;wrt 7.2,r62,r60,r60/r61,r61,r65,r65/r71,r71
90: 0→r60→r61→r62→r65→r71;r20+C[H+1]→r20;r21+1→r21
91: next H
92: wtb 7,12
93: end
*28419
```

```
0: dsp "TRANS. AND ROT. KIN.ENERGY";wait 1500
1: wtb 7,27,86,int(12/64),int(12)
2: ent "MASS OF SUBJECT",r0;dim K[2,14]
3: dim A[22,28],B[22,28],C[27],S[14],M[14],E[2],G[2],Z[2],I[14],A$[80]
4: dim N$[14,6];"HN"→N$[1];"T"→N$[2];"RUA"→N$[3];"RLA"→N$[4];"RH"→N$[5]
5: "LUA"→N$[6];"LLA"→N$[7];"LH"→N$[8];"RT"→N$[9];"RLL"→N$[10];"RF"→N$[11]
6: "LT"→N$[12];"LLL"→N$[13];"LF"→N$[14];fxd 0
7: .5→S[1]→S[2];.436→S[3]→S[6];.43→S[4]→S[7];.28→S[5]→S[8]
8: .433→S[9]→S[10]→S[12]→S[13];.45→S[11]→S[14]
9: .096→M[1];.458→M[2];.033→M[3]→M[6];.019→M[4]→M[7];.0065→M[5]→M[8]
10: .105→M[9]→M[12];.045→M[10]→M[13];.0145→M[11]→M[14]
11: .0248→I[1];1.308→I[2];.0213→I[3]→I[6];.0076→I[4]→I[7]
12: .0005→I[5]→I[8];.1052→I[9]→I[12];.0505→I[10]→I[13];.0038→I[11]→I[14]
13: ent "SUBJECT I.D.",A$;wtb 7,10,10,10,10,10,10,13;wrt 7,"     ",A$,r0,"Kg"
14: wtb 7,10,10;fmt 0,c6,z
15: for Q=1 to 14;M[Q]r0→M[Q];next Q
16: ent "TRK?[0=0,1=1]",r8
17: if r8=0;trk 0
18: if r8=1;trk 1
19: ent "FILE # TO BE USED ?",Q
20: ldf Q,A[*],B[*],C[*]
21: trk 0
22: fmt 8,/,2x,c,/;wrt 7.8,"ENERGY IN JOULE"
23: fmt 9,f6.1,z;wtb 7,32,32,32,32;wtb 7,27,77
24: for J=1 to 14;wrt 7,N$[J];next J;wtb 7,10,13
25: for H=1 to C[27]-1
26: 0→r2→r4;C[H+1]→T
27: for S=1 to 14
28: 1→C
29: for F=H to H+1
30: abs(A[F,S]-B[F,S])S[S]→K
31: abs(A[F,S+14]-B[F,S+14])S[S]→L
32: if A[F,S]<B[F,S];K+A[F,S]→E[C];jmp 2
33: A[F,S]-K→E[C]
34: if A[F,S+14]<B[F,S+14];L+A[F,S+14]→G[C];jmp 2
35: A[F,S+14]-L→G[C]
36: if C=1;M[S]E[C]→r0;M[S]G[C]→r1;r0+r2→r3;r1+r4→r5;r3→r2;r5→r4
37: if A[F,S]-B[F,S]=0;9^98→Z;jmp 2
38: A[F,S]-B[F,S]→Z
39: (A[F,S+14]-B[F,S+14])/Z→Z[C]
40: C+1→C
41: next F
42: if 1+Z[1]Z[2]=0;-1→r6→K[1,S];jmp 2
43: (atn((Z[2]-Z[1])/(1+Z[1]Z[2]))/57.3/T)^2(.5I[S])→K[1,S]→r6
44: (C[1]√((E[2]-E[1])^2+(G[2]-G[1])^2)/100/T)^2(.5M[S])→K[2,S]→r7
45: if S=1;fmt 2,f2.0,x;wrt 7.2,H
46: r6+V→V;r7+U→U;wait 100
47: next S
48: for A=1 to 2;for B=1 to 14;wrt 7.9,K[A,B]
49: if A=1 and B=14;wrt 7.9,"  R= ",V
50: if A=2 and B=14;wrt 7.9,"  T= ",U," SUM= ",U+V
51: next B;wtb 7,10,13;next A
52: 0→U→V
53: next H;wtb 7,8;fmt 3,f3.0;wrt 7.3,C[27];wtb 7,12
54: end
*5540
```